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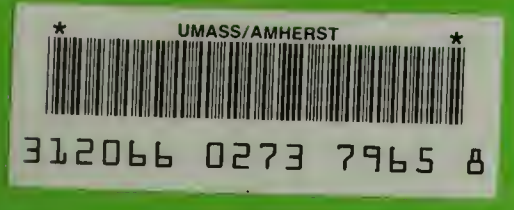

POLLUTANT REDUCTIONS FROM WWTP UPGRADINGS IN MASSACHUSETTS

1978-1988

BY

MARGARET T. WEBBER

TECHNICAL SERVICES BRANCH

DIVISION OF WATER POLLUTION CONTROL

APRIL 1989

DEPARTMENT OF ENVIRONMENTAL QUALITY ENGINEERING

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POLLUTANT REDUCTIONS
FROM WWTP UPGRADINGS IN MASSACHUSETTS
1978-1988

Prepared by:

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ABSTRACT

Pollutant load reductions at ten wastewater treatment plants in Massachusetts that have been upgraded to advanced treatment with nitrification between 1978 and 1988 were evaluated. Reductions in Biochemical Oxygen Demand (BOD), Suspended Solids (SS), Ammonia-Nitrogen (NH3), and Total Phosphorus (TP) mass loadings were studied. Pollutants in the effluent averaged greater than an 85 % load reduction. Pollutant concentrations in the receiving waters below the discharges were also reduced with the treatment plant upgradings. Unless the receiving water had other discharges or water quality affected by associated wetlands, instream dissolved oxygen concentrations improved meeting water quality standards.

Brief cost/benefit analyses were conducted for each facility. Plants were upgraded at an average 1988 dollar equivalent of $5 dollars per gallon and 184 pounds per day of pollutants (BOD, SS, NH3, TP) removed per million dollars spent.

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Introduction

The waters of the Commonwealth of Massachusetts have been degraded over the years from domestic sewage, industrial waste and urban runoff discharges. In 1972 Congress passed the amendments to the Federal Water Pollution Control Act, Public Law 92-500, which set a policy with goals to attain desired water quality across the nation. The Act also provided funds to help finance the water pollution abatement projects to attain and maintain the water quality goals.

Over the years the amount of funding provided by the federal government has decreased. In response, the Commonwealth of Massachusetts has helped provide money to account for the diminishing federal funds. The Construction Grants Section of the Division of Water Pollution Control administers grants to municipalities for initial planning, design and construction of new wastewater treatment facilities and the upgrading of older facilities which are not meeting their NPDES discharge permits or are severely degrading the water quality of receiving streams.

Federal-only grants are provided for the preliminary and final planning steps. Joint state/federal grants are provided for the construction and upgrading of publicly owned treatment works (POTW's). Originally the EPA/state/local shares for construction was 55%/35%/10% respectively. Federal grant assistance is slowly dwindling and the state is starting to take up more of the share. The grants program is also being phased out and a revolving loan fund is being established to finance POTW's. After 1994 there will be no more federal assistance available. To account for the diminishing funds, State and Federal contributions will be provide through loans rather than grants to local communities.

To date, approximately 2.5 billion dollars in federal/state/and local funds have been spent on pollution abatement projects in Massachusetts. The water quality in the rivers and streams of the Commonwealth have improved dramatically as a result of these projects.

The following report investigates ten Massachusetts wastewater treatment plants (WWTP's) that have been upgraded within the past ten years. The improvements in the effluents' quality and in the instream water quality (downstream of the upgraded plants) resulting from the plant improvements is documented in this report. A brief cost/benefit analysis for each plant is also included.

The results indicate that the construction and/or upgrading of wastewater treatment plants has resulted in significant wastewater and water quality improvements. Funding and grants must continue to be provided so that more plants, CSO's and collection systems may be constructed and upgraded to further improve the remaining waters of the Commonwealth.

PROCEDURE

Choice of Treatment Plants

To begin, a list of all the major Massachusetts Wastewater Treatment Plants with advanced treatment processes were listed. Major discharges are plants with flows greater than 50,000 gpd (Abbreviations are defined in Appendix F) and/or containing potentially toxic pollutants. This list (Table 1) includes the name of the plant, the receiving waterbody, the date constructed, the date advanced treatment went on-line, the type of treatment and the National Pollutant Discharge Elimination System permit (NPDES) limits for Flow, BOD, SS, NH3 and Total Phosphorus (TP). From this list ten (10) WWTP's were chosen for study. To narrow the list, eliminations were made for the following reasons. Seven (7) plants are currently in the planning phase or are under construction, and thus cannot be evaluated. Plants that were upgraded for stricter BOD and SS limits, but not ammonia or phosphorus limits were excluded. All plants evaluated had nitrification, while not all plants had phosphorus removal. Plants that discharged to tidal or ocean waters were also eliminated. Any plant upgraded more than ten years ago (prior to 1978) was eliminated since the technology and cost of funding the plant fifteen years ago compared to todays dollars vary significantly. Other plants that went on line recently were also eliminated due to lack of recent WWTP effluent data or river water quality data to document improvements at the Technical Services Branch (TSB) office. The list was reduced to the following ten WWTP's:

-Attleboro WWTP
-Brockton WWTP
-Leominster WWTP
-Mansfield WWTP
-Middleborough WWTP
-Milford WWTP
-North Attleborough WWTP
-Upper Blackstone WPAD
-Ware WWTP
-Westborough Regional WWTP

History

For each plant a brief history was compiled describing the original treatment process, effluent limits, treatment history and operational problems. Further information on downstream water quality and why the plant had to be upgraded was also provided. The year the upgrading construction began and was completed, along with a description of the new plant and its effluent limits, and a brief discussion of the water quality improvements downstream of the discharge are also included.

Wastewater Treatment Plant Loadings

The plants varied in size, in method of treatment, and in receiving water characteristics. For each plant, ten effluent samples from before and ten effluent samples from after the upgrading were tabulated. Pollutant concentration was converted from mg/l to mass discharge pounds/day (lbs/day) using the following equation:

$$cfs * mg/l * 5.4 = lbs/day$$

TABLE 1

LIST OF ALL MAJOR ADVANCED WWTP'S IN MASSACHUSETTS
1988

WWTP	RECEIVING WATER	7Q10 (cfs)	DATE ADV.	TRMT	WWTP FLOW cfs	Eff. limits mg/l BOD	NH3	TP	DO
Pittsfield	Housatonic	25.45	1977	SAST	25.5	10	1.0	1.0	6.0
Gardner	Millers	2.72	UC	SAST	6.56	10	1.0	--	6.0
Winchendon	Millers	6.9	1975	SAST	0.75	15	--	--	--
N. Brookfield	Dunn Bk.	0.5	UC	SAST	0.78	15	1.0	1.0	6.0
Spencer	Cranberry	0.16	UC	SAST	0.93	10	1.0	1.0	6.0
Ware	Ware	19.86	1985	SAST	3.1	25	1.0	1.0	--
Southbridge	Quinebaug	12.92	1987	SAST	3.74	15	2.0	--	6.0
Leicester	French	0.2	UC	SAST	0.54	12	2.0	1.0	6.0
Webster-Dudley	French	12.95	UC	SAST	9.30	10	2.0	1.5	6.0
Hopedale	Blackstone	0.7	1981	SAST	0.91	15	2.0	1.0	--
Northbridge	Blackstone	115.0	1974	SAST	2.79	10	--	--	--
UBWPAD	Blackstone	7.9	1988	SAST	86.8	10	2.0	--	6.0
West Upton	West River	0.5	1972	SAST	0.47	15	--	--	--
Attleboro	Ten Mile	5.6	1980	SAST	13.3	5.0	1.5	1.0	6.0
N. Attleborough	Ten Mile	0.47	1980	SAST	7.13	5.0	1.0	1.0	6.0
Bridgewater	Town River	2.65	1989	AST	2.23	20	3.0	--	6.0
Brockton	Salisbury	0.6	1984	SAWT	27.9	5.0	1.0	1.0	6.0
Mansfield	Threemile	4.2	1985	SAST	4.85	10	1.0	1.0	6.0
Middleborough	Nemasket	2.95	1978	AWT	3.88	7.0	1.0	1.0	7.0
Taunton	Taunton	40.4*	1978	SAST	13.0	15	1.0	--	6.0
CRPCD	Charles	6.0	1979	SAST	7.04	15	--	--	6.0
Medfield	Charles	7.99	1975	AST	2.36	15	--	1.0	6.0
Milford	Charles	0.73	1986	SAWT	6.67	7.0	1.0	1.0	6.0
Fitchburg East	Nashua	17.3	1976	SAWT	19.2	8.0	1.0	1.0	5.0
Fitchburg West	Nashua	8.8	1975	SAWT	23.7	8.0	1.0	1.0	8.0
Leominster	Nashua	31.8	1984	SAST	14.4	15	1.3	1.0	5.0
Hudson	Assabet	14.0	1986	SAST	4.03	15	3.0	--	6.0
Marlborough East	Hop Bk.	0.16	1974	SAWT	8.53	7.0	0.5	0.75	--
Marlborough West	Assabet	9.88	UC	SAST	4.48	15	2.0	--	5.0
Westborough	Assabet	3.51	1987	SAST	11.9	10	1.0	--	6.0
Rockland	French Stm	0.8	1982	SAWT	3.88	6.0	1.0	1.0	7.4
Marion	Aucoot Cove	*	1971	AST	0.78	10	--	--	--
Wareham	Agawam	*	1972	AST	2.79	10	--	--	--
Ware	Ware	19.86	1985	SAST	3.1	25	1.0	1.0	--

UC - Under Construction
SAST - Seasonal Advanced Secondary Treatment (BOD<30 mg/l)
AST - Advanced Secondary Treatment (year round BOD limits, BOD<30 mg/l)
SAWT - Seasonal Advanced Wastewater Treatment (BOD<10 mg/l)
AWT - Advanced Wastewater Treatment (year round BOD limits, BOD<10 mg/l)
-- - No Limit
* - Tidal

For some treatment plants, ten days of effluent data were not available. Average lbs/day loadings were thus determined from available data. Based on the before and after loadings, an average percent reduction in pollutant loading was calculated. These data are tabulated in Appendix A and summarized in Tables 2 and 3.

River Loadings

To determine a reduction in river loading for each treatment plant already studied, all the "before" and "after" water quality survey data were collected. If a "before" and an "after" survey had similar flows during similar weather conditions (i.e., sunny days with similar water temperatures), then the instream concentrations and the mass loadings for the two surveys were calculated for one station above and three to four stations below the discharge. Four stations data were compared to note the effluents impact, improvements or effect on dissolved oxygen sags that result. Instream comparisons are tabulated in Appendix B and plotted.

Cost/Benefit

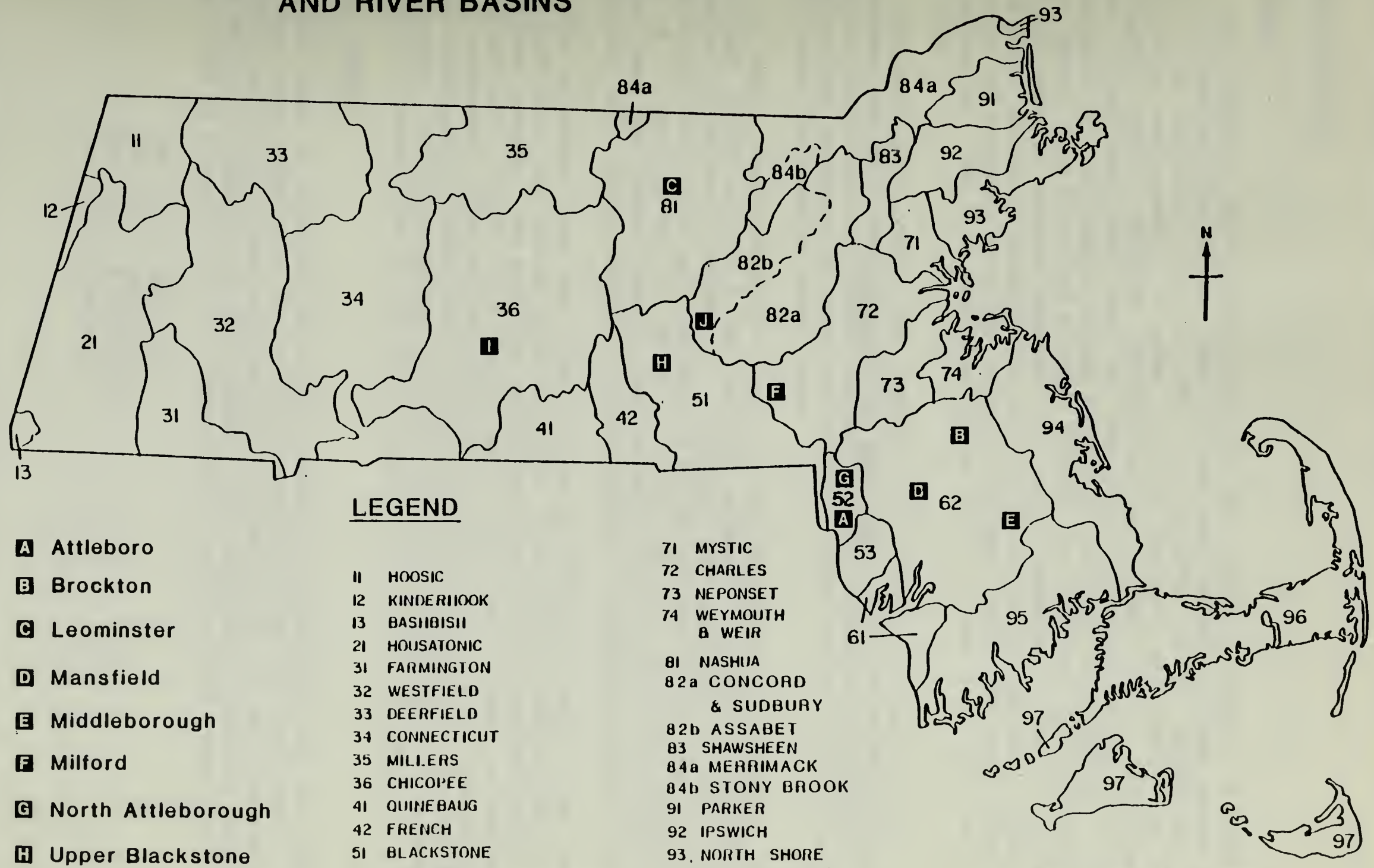
The cost for planning (Step 1), designing (Step 2) and construction (Step 3) of each WWTP's upgrading was obtained by reviewing the construction grant files in the Boston DEQE office. The total cost was broken down into Federal, State and Local shares and is summarized by WWTP in Table 4. The percent contribution by the federal and state grants varied based on when the treatment plant was constructed and whether any innovative or alternative treatment methods were employed.

Since each treatment plant was upgraded during a different year, and inflation causes a different value for the dollar each year, each total cost was converted to 1988 costs using the Engineering News Record (ENR) index. The ENR table on Construction Cost Index History (Appendix E) gives a four digit number as the annual average for each year. When divided by the year the cost is to be related to (i.e., 1988 in this study), a factor is produced. When this factor is multiplied by the original cost, the corresponding 1988 cost is obtained. For each WWTP a factor was determined based on the year the construction began and the year 1988. Thus the equivalent cost for each plants construction in 1988 dollars was determined and is also summarized in Table 4.

The total cost (in millions of dollars) was then divided by the total design flow of the plant in MGD to give the cost/gallon of construction. The cost/gallon for each of the ten WWTP's is summarized in Table 5.

Next, the pounds/day of BOD, SS, NH3 and TP in each treatment plant before and after upgrading were compared. The sum of all the differences in loadings were added together to get a total pounds per day removed. This was divided by the 1988 cost of the plant to get pounds per day removed per million dollars. Since the plants were not operating at full capacity, load removals were also flow adjusted to determine lbs/day removed per total cost. Each individual plants calculations can be found in Appendix C and the summary for every WWTP is presented in Table 6. The pounds per year were not determined since loadings were based on the most stringent permit limits which are often seasonal. Individual pollutant cost comparisons were determined and tabulated for each plant.

Figure 1 LOCATION OF WASTEWATER TREATMENT PLANTS AND RIVER BASINS



LEGEND

- A Attleboro
- B Brockton
- C Leominster
- D Mansfield
- E Middleborough
- F Milford
- G North Attleborough
- H Upper Blackstone
- I Ware
- J Westborough Regional

- 11 HOOSIC
- 12 KINDERHOOK
- 13 BASHBISH
- 21 HOUSATONIC
- 31 FARMINGTON
- 32 WESTFIELD
- 33 DEERFIELD
- 34 CONNECTICUT
- 35 MILLERS
- 36 CHICOPEE
- 41 QUINEBAUG
- 42 FRENCH
- 51 BLACKSTONE
- 52 TEN MILE
- 53 NARRAGANSETT BAY (shore)
- 61 MOUNT HOPE BAY (shore)
- 62 TAUNTON

- 71 MYSTIC
- 72 CHARLES
- 73 NEPONSET
- 74 WEYMOUTH & WEIR
- 81 NASHUA
- 82a CONCORD & SUDBURY
- 82b ASSABET
- 83 SHAWSHEEN
- 84a MERRIMACK
- 84b STONY BROOK
- 91 PARKER
- 92 IPSWICH
- 93 NORTH SHORE
- 94 SOUTH SHORE
- 95 BUZZARDS BAY
- 96 CAPE COD
- 97 ISLANDS

EVALUATION OF TEN WWTP'S

ATTLEBORO WWTP

History

The Attleboro WWTP (NPDES Permit No. MA0100595) discharges to river mile 7.3 of the Ten Mile River. The WWTP was constructed in three stages. The plant was initially built in 1912 and consisted of 26 intermittent sand filtration beds covering 16 acres. In 1949 the plant was expanded to include screening, primary settling, chlorination and sludge drying. Officials from Rhode Island complained that the town was discharging inadequately treated wastewater to the river upstream from their drinking water supply. In 1964 grit removal, two high rate tricking filters, two secondary settling tanks, one primary and one secondary digester, and a bar screen were added to the plant. The plant was thus converted to a 4.0 MGD secondary treatment plant with primary and secondary settling, trickling filters, slow rate sand filters, and chlorination. The WWTP discharges to the Ten Mile river at a 7Q10 low flow of 5.6 cfs.

Instream water quality was degraded as a result of the effluent. High instream nutrient concentrations from the plant caused excessive algae growth and eutrophication and solids settling in the downstream impoundments. In addition the extension of sewers was needed to serve the developed areas of the city beyond the existing sewer system.

In early 1978 construction began on the expansion and upgrading of the Attleboro plant to a 8.6 MGD advanced wastewater treatment facility with tertiary rapid sand filtration. The plant was completed in 1980 and has year-round limits of 5 mg/l for BOD and SS and seasonal limits (May 1 - October 31) of 1.0 mg/l for NH3 and TP, and 6.0 mg/l for DO. The plant currently has flows less than design capacity and currently only operates the second stage. The plant is being operated in a modification of the extended aeration mode.

The Attleboro Plant has large amounts of industrial waste (from jewelry manufacturers and metal platers) that occasionally cause upsets in the treatment process. The plant has undertaken a strict pretreatment program that requires every industry that discharges to the sewer to have pretreatment of their wastewater. The program seems to be reducing the metal concentrations which occasionally caused toxic effects and process upsets to the biological operations. A better quality effluent from the upgraded WWTP has reduced the organic pollutant loads in the river, particularly for BOD and ammonia.

WWTP Loading

Ten days of effluent data from before the upgrading and ten days of effluent data from after the upgrading were collected for comparisons. Mass loading calculations were made for BOD, SS, NH3 and TP for each day, based on the effluent concentration and effluent flow. Significant pollutant reductions were noted as a result of the Attleboro WWTP's upgrading (See Appendix A).

BOD - 86 % Reduction
SS - 75 % Reduction
NH3 - 94.5 % Reduction
TP - 50 % Reduction

River Loading

The Ten Mile River was sampled extensively in 1973, 1981 and 1984. The 1984 survey was a series of five extensive one-week surveys conducted throughout the summer. The 1981 survey was conducted one year after the WWTP had been upgraded, and the WWTP did not appear to be meeting its NPDES permit limits or operating well. Furthermore, no instream flow measurements were taken during the 1981 survey.

Two surveys were chosen for comparison based on similar flows and water temperature conditions. The survey conducted on July 5, 1973 was compared to the July 24-25 1984 survey. Instream flow measurements were taken at river mile 7.0 during both surveys. In 1973 a flow of 70 cfs was measured and in 1984 a flow of 69 cfs was measured. The flows at the remaining stations were estimated, based on other known inputs (the WWTP and Seven mile River flows) and the rivers flow profile.

Four river stations were chosen for instream data comparison, one station from above the WWTP at river mile 8.0, (the WWTP is at river mile 7.3) and three stations below the WWTP at river miles 7.0, 5.8, and 3.2. Mass loading calculations were made based on streamflow and the instream concentration. Data are tabulated in Appendix B, and graphed in Figures 2-4.

The instream pollutant loadings were lower in 1984 than in 1973 for every parameter (BOD, SS, NH3, and TP). Suspended solids and ammonia-nitrogen had larger pollutant reductions than other parameters. The upstream water quality was slightly better in 1984, than in 1973 causing some of the decrease. Upstream water quality was better as a result of the elimination or pretreatment of industrial discharges, and the upgrading of the Attleboro facility upstream.

Dissolved oxygen concentrations between the two surveys were similar. The minimum dissolved oxygen was very similar, while the 1984 maximum dissolved oxygen concentrations were slightly higher than the 1973 concentrations.

Cost/Benefit

The total cost to plan, design and construct the Attleboro WWTP, and construct a force main and two pumping stations with a 1977 grant was $32,136,000. This was paid for by federal grants of $23,073,000 (71.8 %), state grants of $4,659,000 (14.5 %) and local funds of $4,404,000 (13.7 %). This total cost in 1988 dollars is equivalent to $52,253,000.

The 8.6 MGD plant was upgraded at a cost of $3.74 per gallon, or $6.08 per gallon 1988 dollars. The average total loadings of BOD, SS, NH3 and TP removed by the upgraded plant was 2,546 lbs/day. This would be 79.2 lbs/day removed per million dollars or 48.7 lbs/day removed per 1988 equivalent dollars. The plant is currently at 66.8% of its design capacity. When the pounds per day removed is proportionally adjusted to the full capacity, a rate of 72.9 pounds per day of pollutants are removed per 1988 million dollars spent.

The $32.1 million spent increased the cities sewerage system and improved the WWTP's effluent concentrations significantly. The instream water quality also benefited with lower organic and nutrient loadings and slightly higher dissolved oxygen concentrations.

FIGURE 2

TEN MILE RIVER

BOD AND SS COMPARISONS – ATTLEBORO WWTP

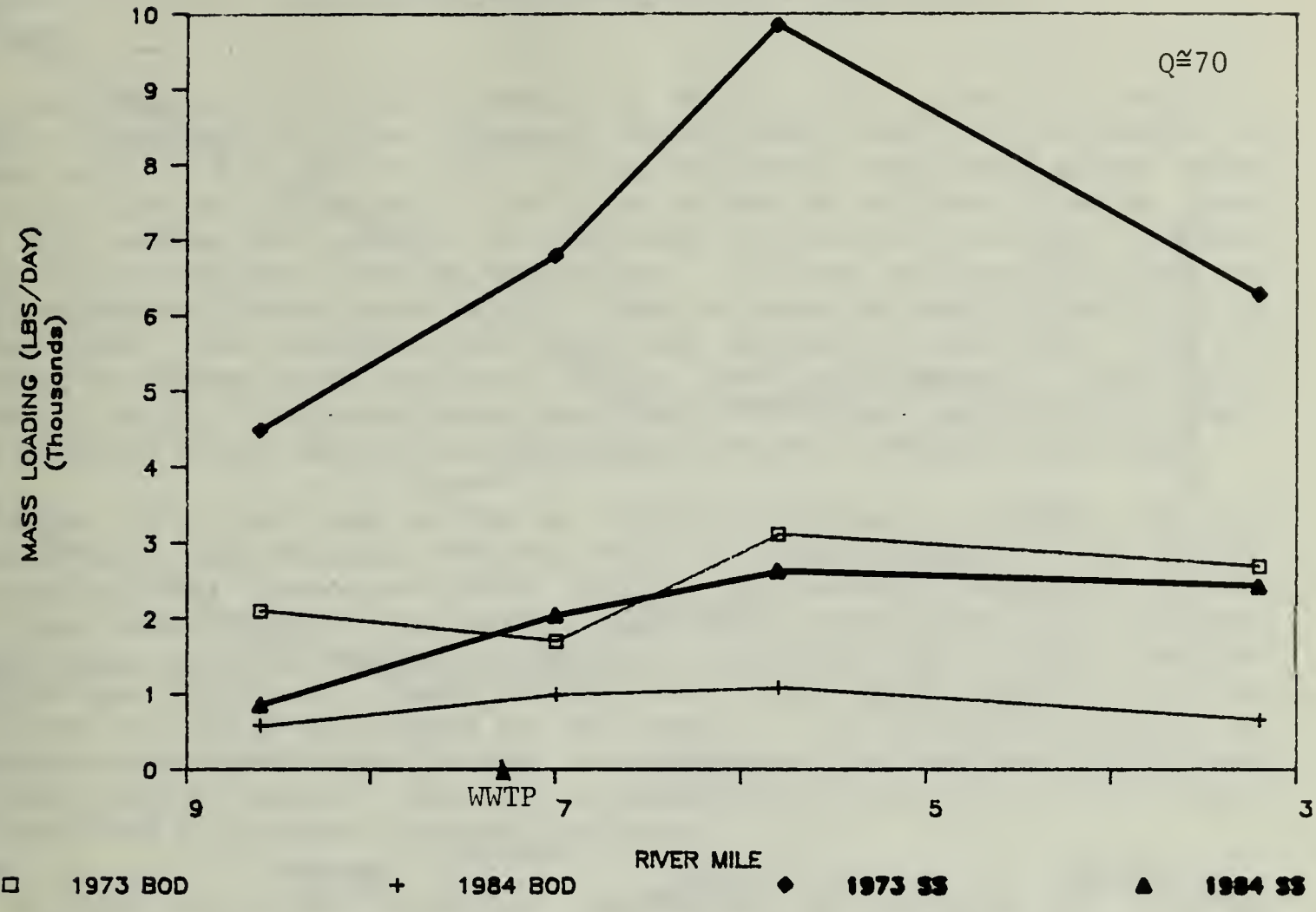


FIGURE 3

TEN MILE RIVER

NH3 AND TP COMPARISONS – ATTLEBORO WWTP

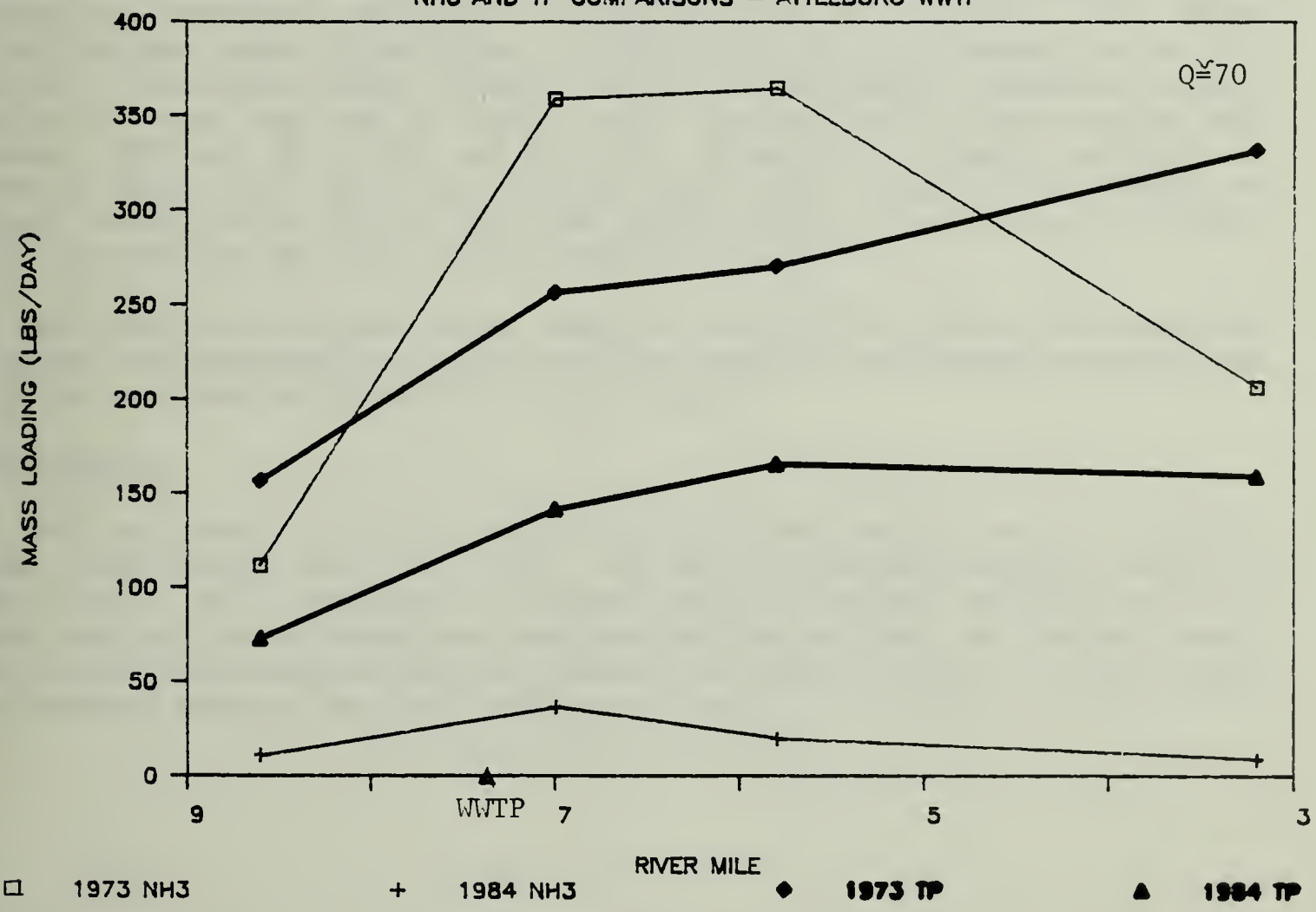
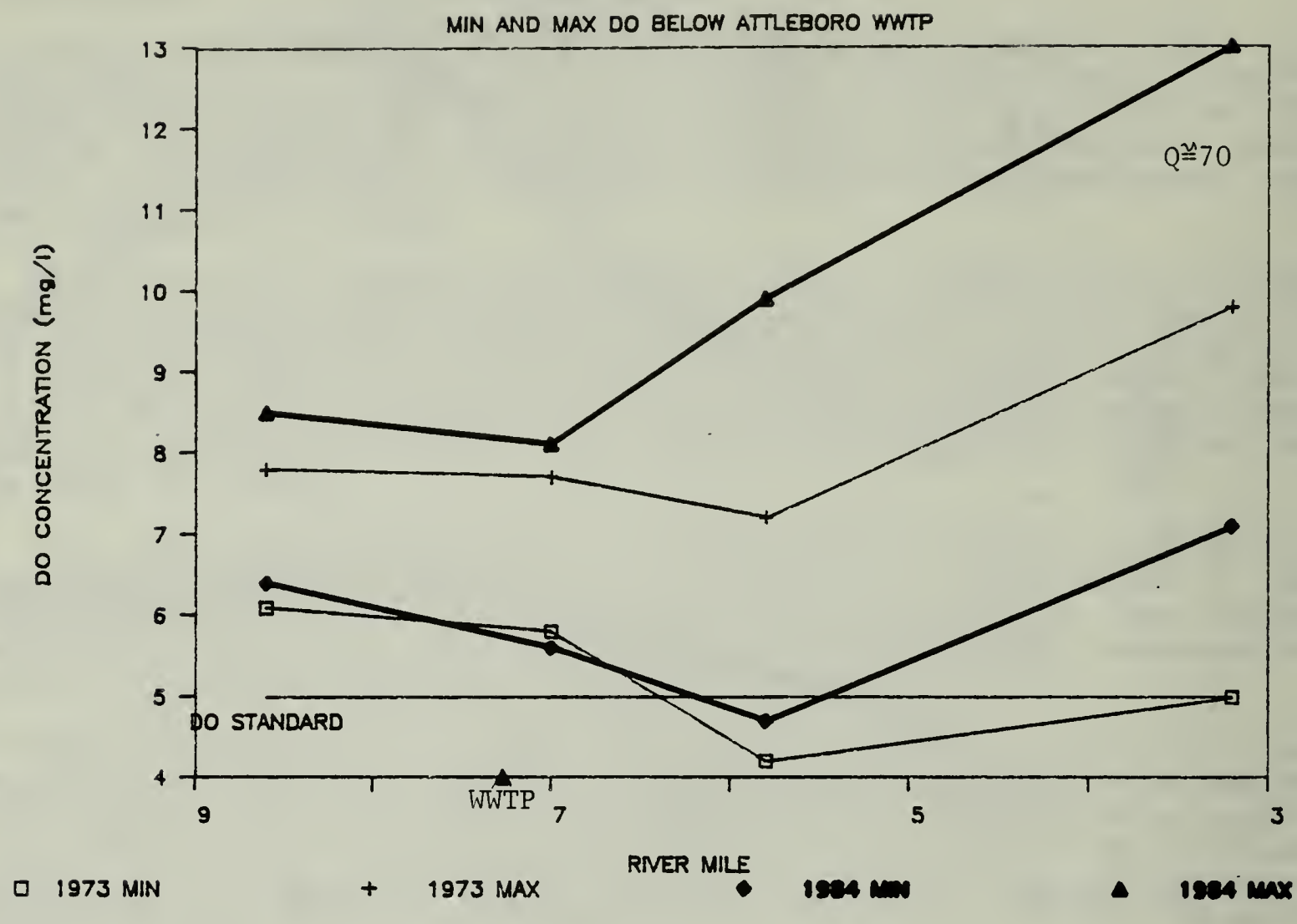


FIGURE 4

TEN MILE RIVER



BROCKTON WWTP

History

The Brockton WWTP (NPDES permit No. MA0101010), located in Brockton, Mass., discharges to the Salisbury Plain River near its headwaters at river mile 48.5. The original 15 MGD secondary activated sludge plant went on line during 1962-3. The large volume of effluent from the plant (15 MGD) versus the low flow of the river, (7Q10 flow =0.6 cfs), provided very little dilution for the wastewater. At peak effluent flow and low flow conditions there would be 46.5 times as much effluent in the river as river flow. The Brockton WWTP also had operational problems and the collection system exhibited high inflow and infiltration. Peak hourly flows of up to 64 MGD had been recorded at the plant during wet weather. The combined sewers and wet weather flows would often bypass the plant.

Thus, with the large volume of effluent compared to stream flow, the history of operational problems and the poorly treated wet weather discharges, the downstream water quality was severely impacted, and did not meet water quality standards. The river experienced high instream phosphorus, ammonia, solids and coliform concentrations and low dissolved oxygen. The treatment plant discharge and urban runoff caused extensive build-up of solids downstream of the outfall. The settled solids in the sediments contained high nutrient concentrations and exerted significant sediment oxygen demand. The City of Brockton was ordered by the Division in June 1976 to provide advanced treatment.

A 1976 wasteload allocation recommended further BOD and nitrogen removal during the summer months and year-round phosphorus removal. In 1980 Brockton began construction to expand and upgraded its secondary plant to advanced treatment. The project also included construction of an interceptor to serve the towns of Avon, Whitman and part of Abington. The upgrading expanded the plant from 12 MGD to 18 MGD, and added nitrification, sand filtration, disinfection and post-aeration to the secondary activated sludge plant. Sludge is digested, pressure-filtered and incinerated; the ash is landfilled. The new limits are stricter with seasonal BOD and SS limits of 5.0 mg/l from May 1 through October 31, seasonal limits of 1 mg/l for ammonia, and 7 mg/l for dissolved oxygen and a year round limit of 1.0 mg/l for phosphorus. From November through April the BOD and SS limit is increased to 15 mg/l.

The upgraded treatment plant went on line in late 1985. The improved effluent has enhanced the instream water quality, but concerns associated with the instream solids build-up still exist.

WWTP Loading

The WWTP went on line in 1985, has only been sampled by the Division three times during the year 1988, and was not sampled between 1985 and 1988. Thus when comparing the mass loading effluent calculations only three sets of "after data" are compared to the ten days of "before data". Two of the after days were during the first days of the stricter limits when ammonia removal was just getting started.

The before and after data mass loading calculations are presented in Tables A-3 and A-4 of Appendix A. Even though adequate after data do not exist, considerable improvements were noted. The pollutant reductions for the Brockton WWTP are as follows:

BOD - 86.5 % Reduction
SS - 98 % Reduction
NH3 - 66 % Reduction
TP - 66 % Reduction

River Loadings

Three water quality surveys were conducted in 1983 to document the before water quality and measure biological impacts from the WWTP. Only one 1983 survey included flow measurements. Since the WWTP's upgrading, only one water quality survey has been conducted (on 9/28/88) on the Salisbury Plain River and fortunately exhibited similar flow measurements to the flow measurements taken during the July 19, 1983 survey. The two surveys compared were 7/19/83 vs. 9/28/88. The temperatures were different so percent saturation comparisons are made for dissolved oxygen as well as instream dissolved oxygen concentrations.

Comparisons were made by calculating the mass loadings of various parameters at one station upstream of the discharge (river mile 49.1) and four stations below the discharge (river miles 48.4, 47.1, 45.6, and 44.5). The treatment plant discharges at river mile 48.5. Flows for each station were based on two known instream flow measurements, a known effluent discharge and interpolations. See Appendix B for tabulations and refer to Figures 5-8 for plots.

Water quality improvements were most noticeable in the dissolved oxygen (DO) and nutrient concentrations. As a result of the WWTP upgrading, instream ammonia concentrations decreased from 17 mg/l observed in 1983 to less than 1 mg/l observed in 1988. With the decrease in ammonia there was a corresponding increase in nitrate-nitrogen from the treatment plants nitrification process.

Although the WWTP was discharging lower BOD and suspended solid concentrations, the river still experienced an increase in instream BOD and SS concentrations. The water quality upstream of the Brockton WWTP was worse in 1988 than in 1983. A lot of construction was occurring on the banks of the Salisbury Plain River. Runoff from the construction, upstream conditions or instream sediments could be contributing to the increased solids.

The Salisbury Plain River did exhibit definite increases in dissolved oxygen. Results from the 1983 survey indicated a large DO sag (down to 1.5 mg/l and 15 % saturation) three miles downstream from the WWTP. In 1988 the lowest dissolved oxygen was 6.2 mg/l (60 % saturation) at the upstream station. Below the WWTP the lowest observed dissolved oxygen was 6.5 mg/l (70 % saturation) one and one half miles below the WWTP, increasing to a minimum of 7.0 mg/l three miles downstream. The dissolved oxygen increase is a result of diminished organic matter and ammonia instream to consume the oxygen during biodegradation.

Cost/Benefit

The total cost to plan, design and construct the upgraded Brockton WWTP was $49,332,000. This was funded by a federal grant of $39,124,000 (79.3 %), a state grant of $5,798,000 (11.8 %) and local funds of $4,410,000 (8.9 %). This total amount is equivalent to $68,818,000 in 1988 dollars.

The 18 MGD plant was constructed at a cost of $2.74 per gallon or $3.82 per gallon 1988 dollars. An average of 16,003 pounds per day of BOD, SS, NH3 and TP were removed by the upgraded plant. This is equivalent to 324.5 lbs/day per million dollars or 232.5 lbs/day per 1988 equivalent dollars (See Table C-2, Appendix C). The plant is currently operating at 68.8% of its design capacity. When the pounds per day is proportionally adjusted to the full design, a rate of 337.9 pounds per day of pollutants are removed per 1988 equivalent million dollars.

The $49.3 million spent to upgrade the WWTP resulted in noticeable benefits to both the WWTP effluent and the instream water quality. The decreases in nutrient and organic loadings to the river were enough to raise the dissolved oxygen to concentrations above water quality standards.

FIGURE 5

SALISBURY PLAIN/MATFIELD RIVER

BOD AND SS COMPARISONS

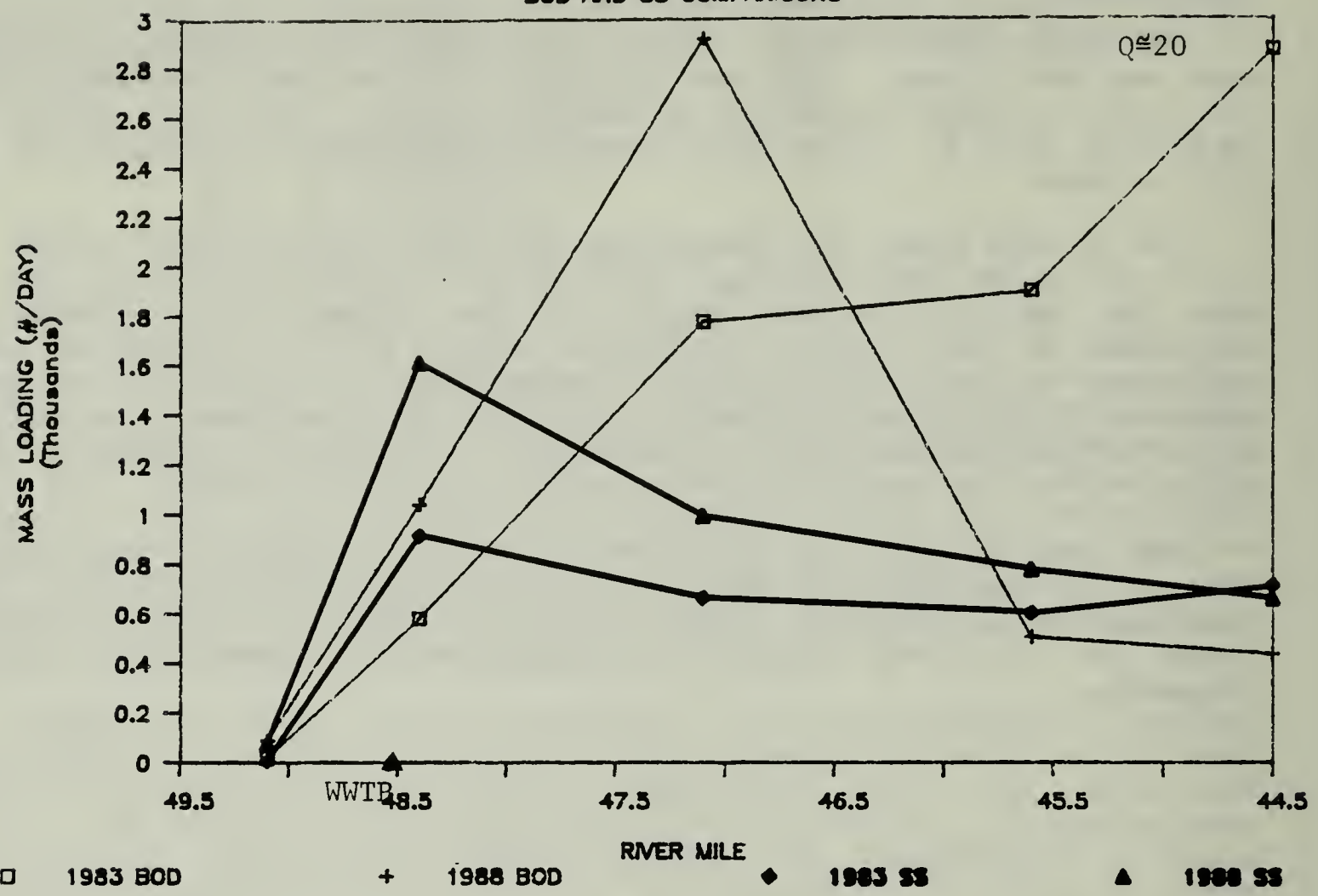


FIGURE 6

SALISBURY PLAIN/MATFIELD RIVER

NUTRIENT COMPARISONS

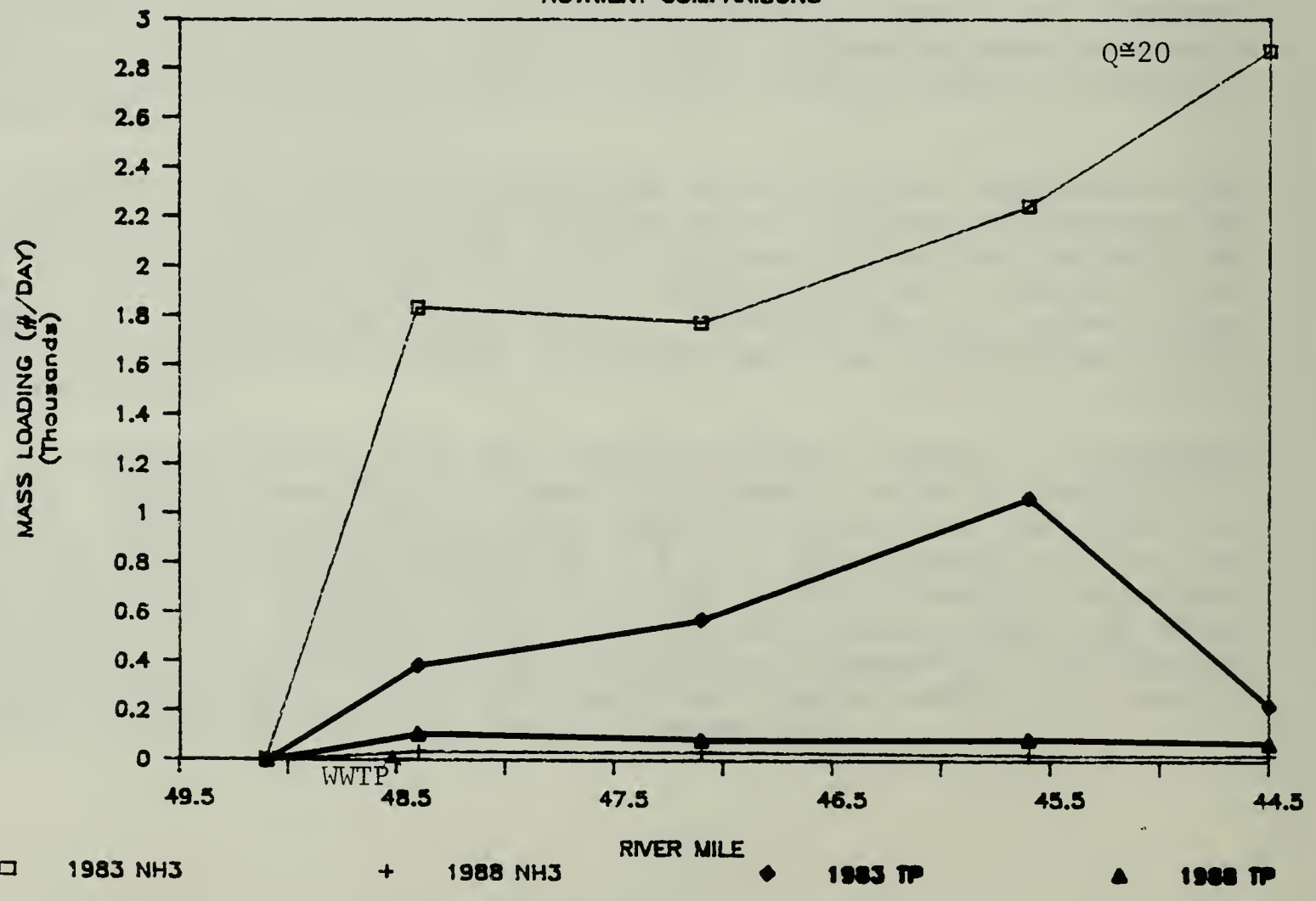


FIGURE 7

SALISBURY PLAIN/MATFIELD RIVER

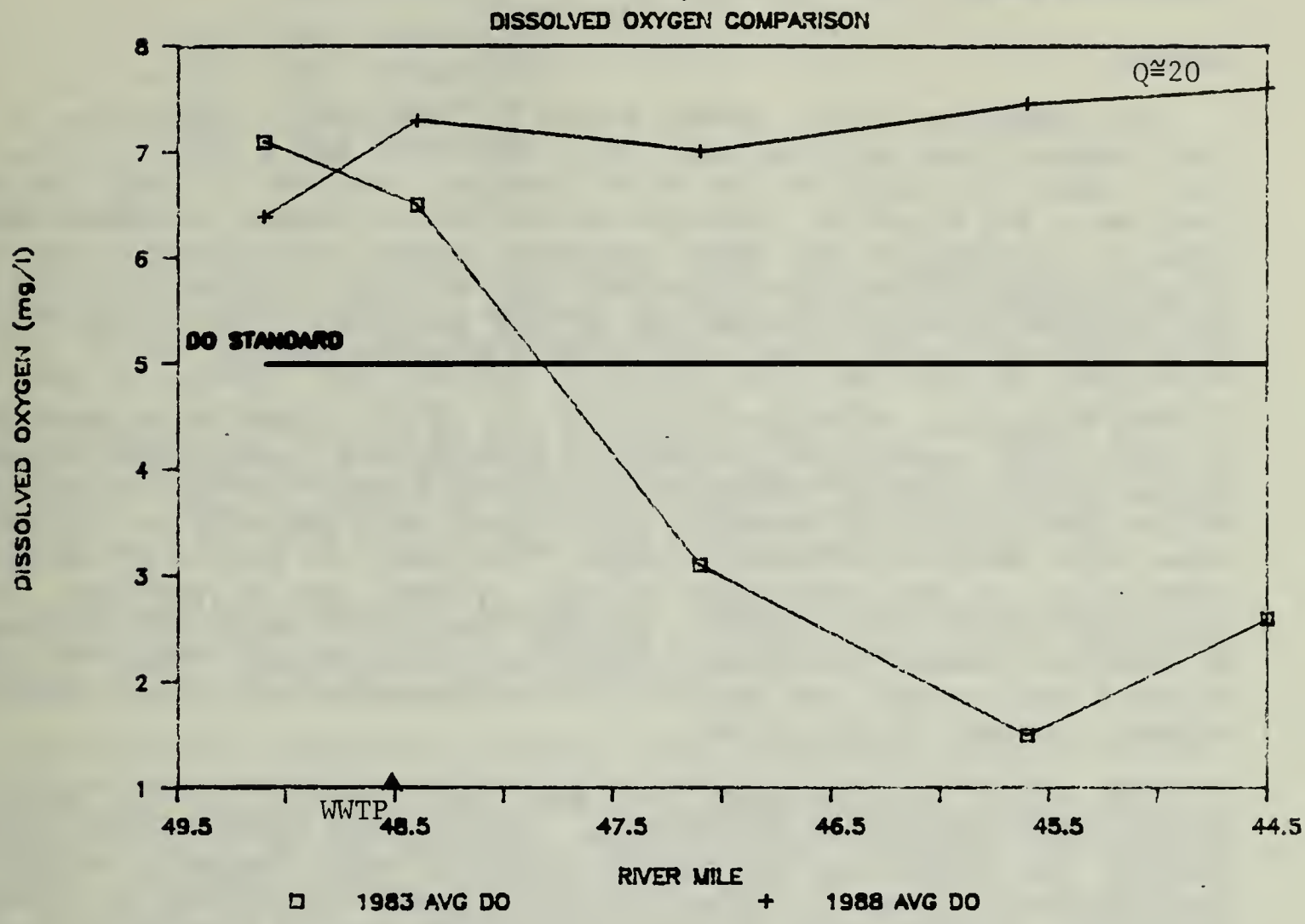
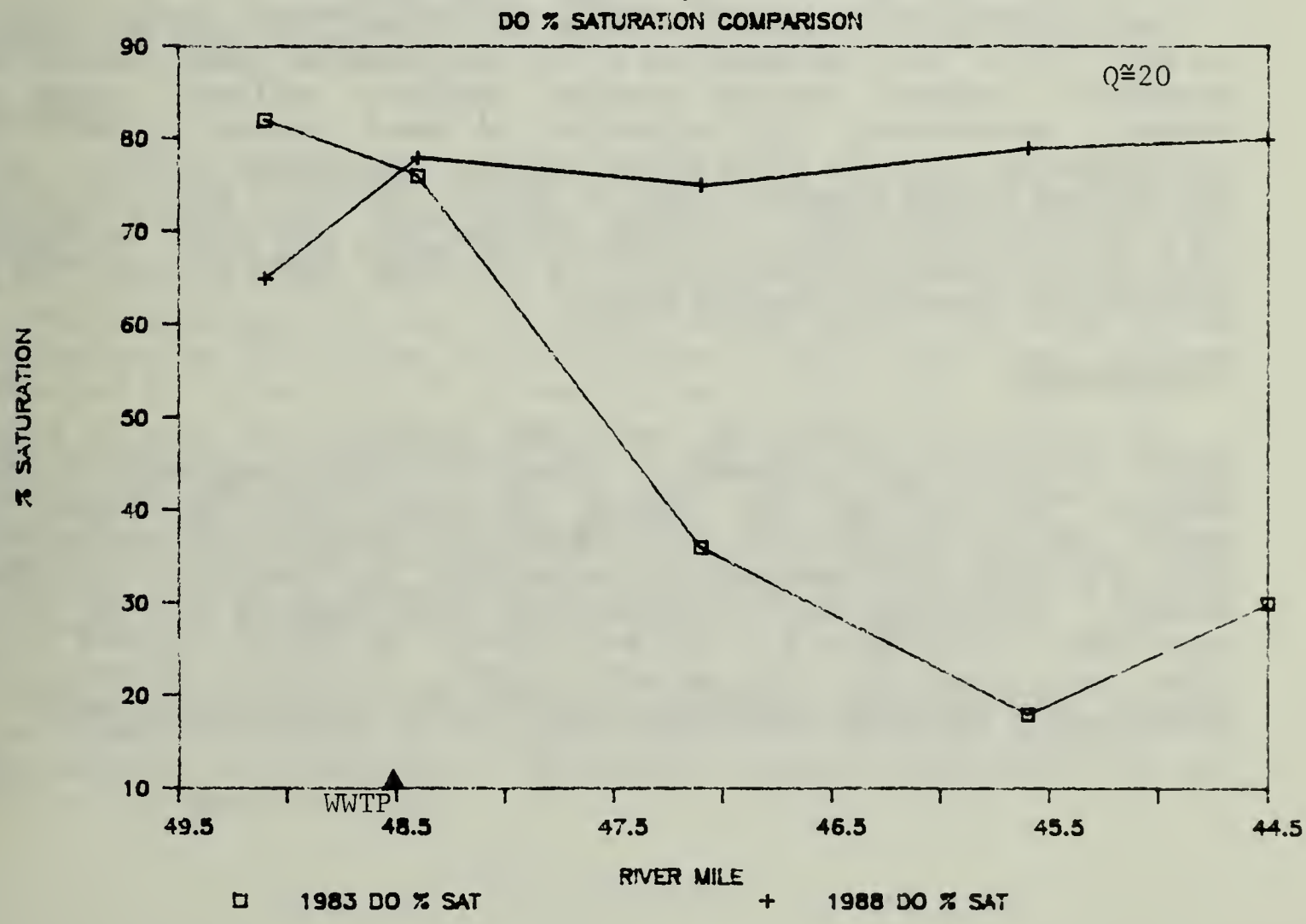


FIGURE 8

SALISBURY PLAIN/MATFIELD RIVER



LEOMINSTER WWTP

History

The Leominster WWTP, (NPDES Permit No. MA0100617) discharges to the North Nashua River at river mile 46.4. The river has a 7-day, 10-year low flow (7Q10) of 31.8 cfs at this location, and the 9.3 MGD effluent receives a 2:1 dilution. Upstream of the WWTP discharge the North Nashua River is impacted by two other treatment plants; the Fitchburg West WWTP at river mile 55.8 and the Fitchburg East WWTP at river mile 48.5. Both are advanced treatment plants but in the past have caused high BOD and solid loadings to the river. (Particularly Fitchburg West).

The Leominster WWTP was originally one of the oldest secondary plants in the state, constructed in the 1930's using the conventional activated sludge process with an average daily flow of 2 MGD. In 1963 the addition of new treatment units increased the average daily capacity to 6.0 MGD and added step aeration activated sludge. The plant was thus a 6.0 MGD plant consisting of two activated sludge systems run in parallel, final clarification and chlorination. The WWTP was often overloaded as a result of combined sewers, stormwater runoff and infiltration. When the flows exceeded the capacity of the plant, the wastewater was often discharged without treatment to the river.

The water quality below the WWTP was impacted by the secondary effluent and numerous sewer overflows, causing high concentrations of BOD, ammonia and phosphorus. The plant primarily treats domestic wastes but also receives industrial wastes from small plastic industries and Chemical companies. In April 1974 the DWPC ordered the City of Leominster to clean up the pollution by upgrading their WWTP, and establishing a ban on sewer tie-ins.

Construction of the new plant began in October 1980, and was completed in April 1984. The new plant is an 9.3 MGD advanced plant consisting of phosphorus removal through chemical addition, activated sludge with ammonia conversion, BOD polishing by sand filtration and final clarification. The new NPDES permit requires year-round limits of 15 mg/l for BOD and SS and seasonal limits of 2 mg/l for NH3, 1 mg/l for TP and 5 mg/l for DO from May 1 through October 31. The city is currently initiating a rehabilitation program for the sewer lines to eliminate some overflows and separate combined sewers.

WWTP Loading

To compare the before and after WWTP loadings, ten days of effluent data and flows were compared. Since the WWTP's upgrading in 1985, however, the DWPC has only sampled the plant five times during water quality surveys conducted in 1985, immediately after the upgrading. During 1985 the plant was experiencing operational problems with its ammonia removal. Thus, ten days of before data were compared to five days of after data (See Tables A-5 and A-6 Appendix A). Even with the limited after data, and the poor ammonia removal, pollutant reductions were observed. The following reductions were noted at the Leominster WWTP:

BOD - 68 % Reduction
SS - 57 % Reduction
NH3 - 32 % Reduction
TP - 81 % Reduction

River Loading

The only river surveys conducted since the treatment plant was upgraded were three synoptic surveys in May, June and September 1985. Surveys before the upgrading were conducted in 1977 and 1979. There were two sets of surveys with similar flows and thus two sets of comparisons were made; 7/31/79 vs. 6/3/85 and 8/27/79 vs. 9/3/85. Flow measurements were obtained from the USGS gage at river mile 43.8. Flows for the remaining stations were estimated based on the WWTP effluent flow and river mile. Both surveys were conducted under flows that were well above the 7Q10 low flow of 35.5 cfs at the POTW (flows were 80 and 90 cfs).

Comparisons were made for one station above the discharge (river mile 47.8, the discharge is at river mile 46.4), and three stations below the discharge (river miles 45.8, 43.8, and 39.8).

The July/June comparisons revealed more noticeable decreases in NH3, phosphorus and suspended solids and slightly higher dissolved oxygen's than did the Aug/Sept comparisons. The Aug/Sept comparison showed slight decreases in BOD, SS and NH3; and a more definite decrease in phosphorus loading. Dissolved oxygen concentrations were well above 5.0 mg/l in 1979, but were one mg/l or higher in 1985. Since the July/June comparisons had different water temperatures, the dissolved oxygen should be compared with percent saturation rather than concentration. Even so, there were noticeable improvements in the saturation, with concentrations up to 90%. The comparisons are tabulated in Tables B-3 and B-4 (Appendix B), and plotted in Figures 9-14.

Cost/Benefit

The total cost to plan, design and construct the upgraded Leominster WWTP and to install 6400 linear feet of interceptor sewers was $25,880,000. This was funded by a federal grant of $18,215,000 (70.4 %), a state grant of $3,636,000 (13.9 %), and local funds of $4,029,000 (15.4 %). When converted from the 1980 grant to 1988 dollars the total amount is equivalent to $36,103,000 in 1988 dollars. The 9.3 MGD plant thus was constructed at a cost of $2.78 dollars/gallon or $3.88 1988 dollars/gal.

An average of 2,331 pounds per day of BOD, SS, NH3, and TP are removed daily due to the upgrading. This is 90.1 lbs/day per million or 64.6 lbs/day per 1988 equivalent million dollars (See Table C-3, Appendix C). The plant is currently operating at 55.5% of its design capacity. When the lbs/day removed is proportionally adjusted to full capacity, a rate of 116.3 lbs/day of pollutants are removed per 1988 million dollars spent.

The 25.9 million dollars spent on upgrading and expanding the WWTP caused beneficial affects to the water quality and dissolved oxygen of the Nashua River. The expansion of the plants' capacity also allows for the tie-in of any sewer overflows.

FIGURE 9

NORTH NASHUA RIVER

BOD AND SS COMPARISONS 8/79 TO 9/85

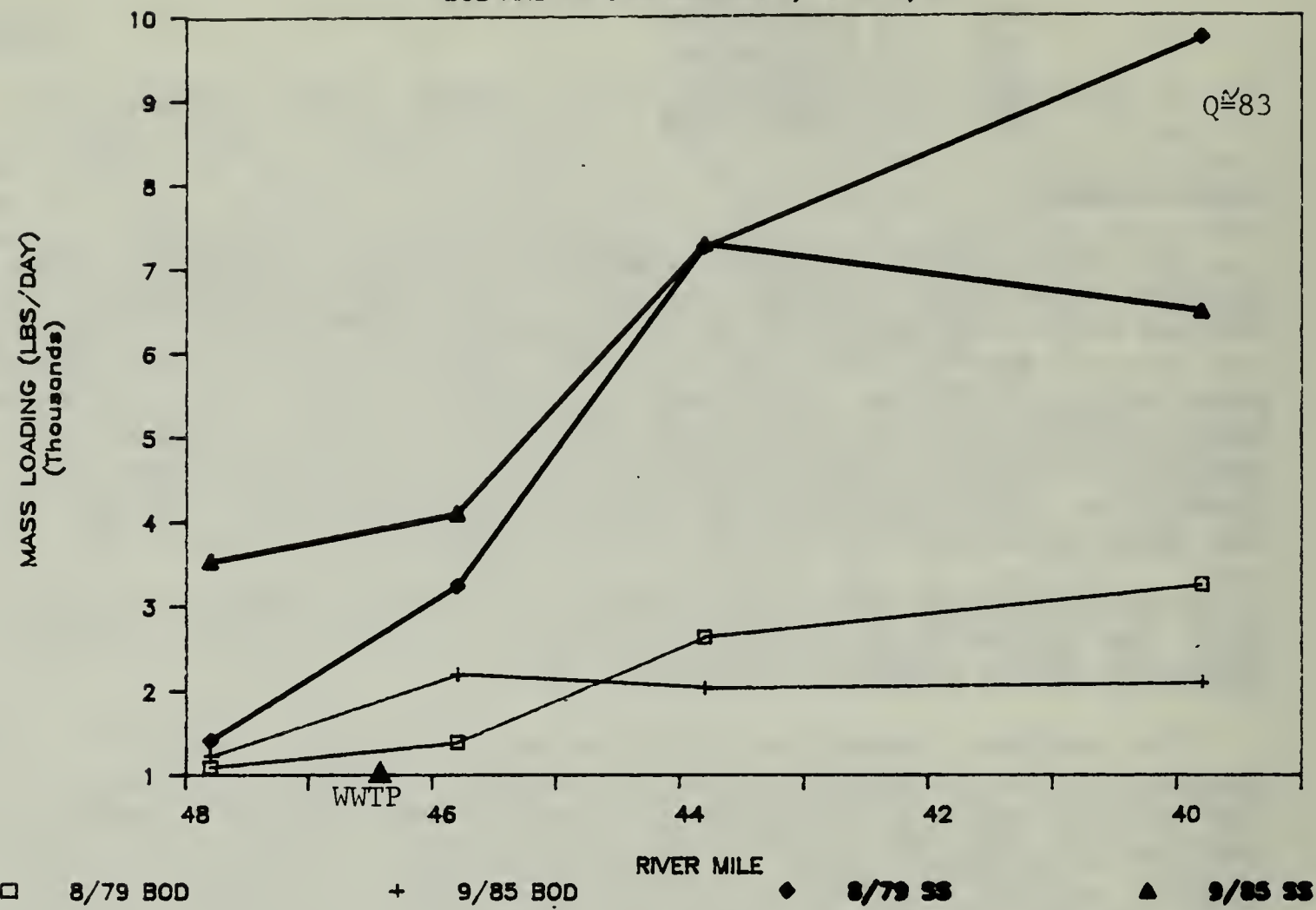


FIGURE 10

NORTH NASHUA RIVER

NH3 AND TP COMPARISONS 8/79 TO 9/85

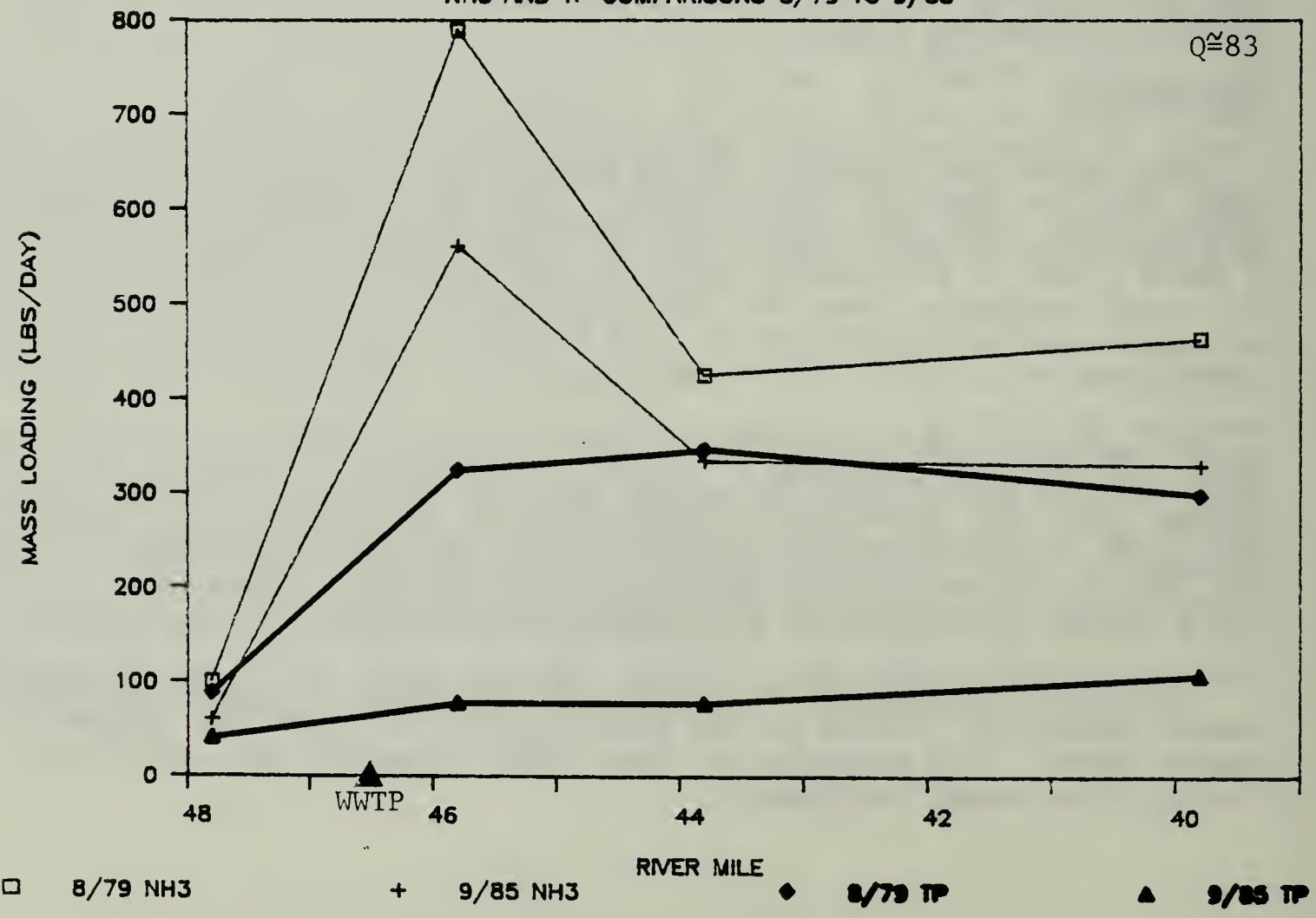


FIGURE 11

NORTH NASHUA RIVER

DO COMPARISONS 8/79 TO 9/85

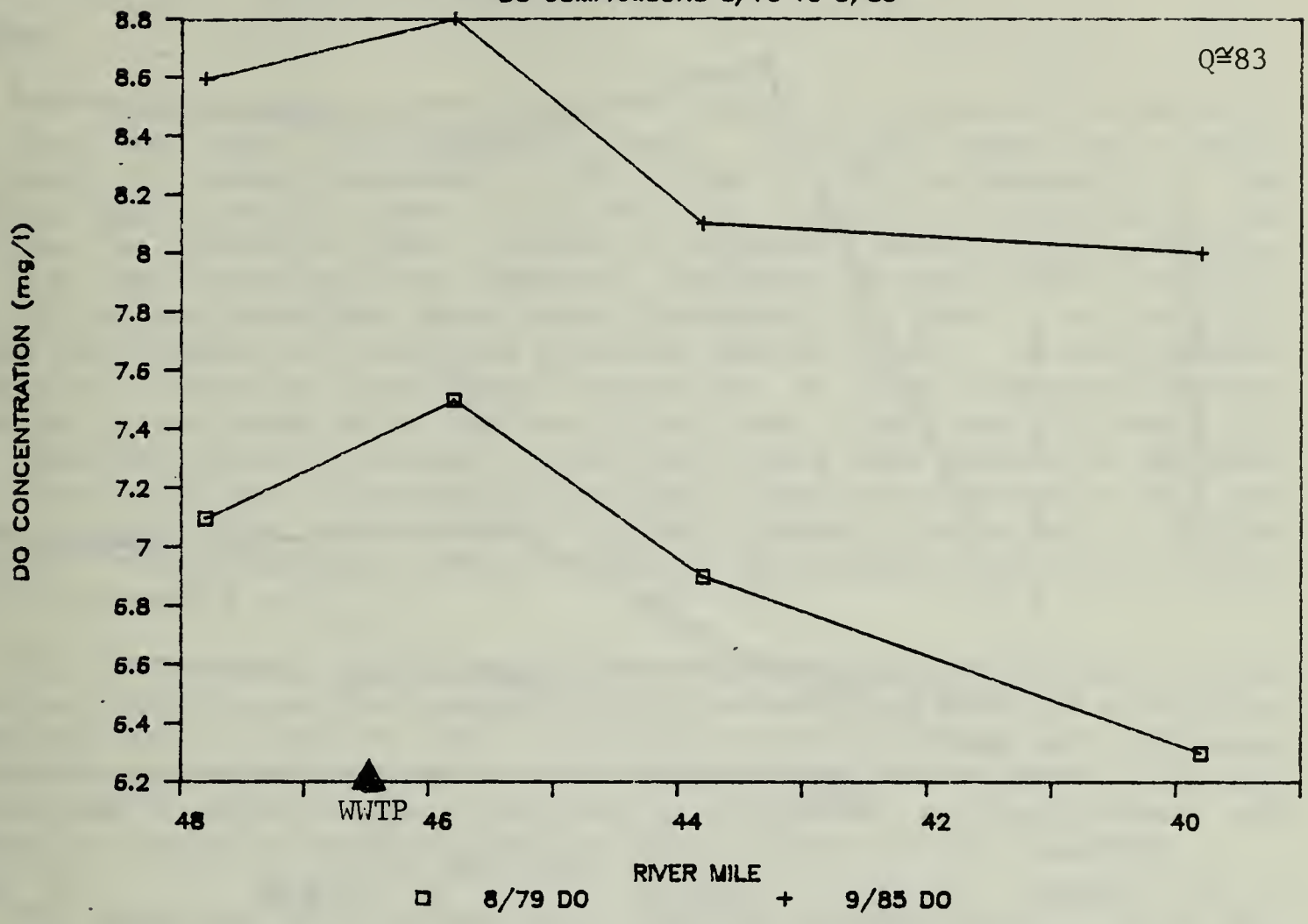


FIGURE 12

NORTH NASHUA RIVER

DO COMPARISONS 7/79 TO 6/85

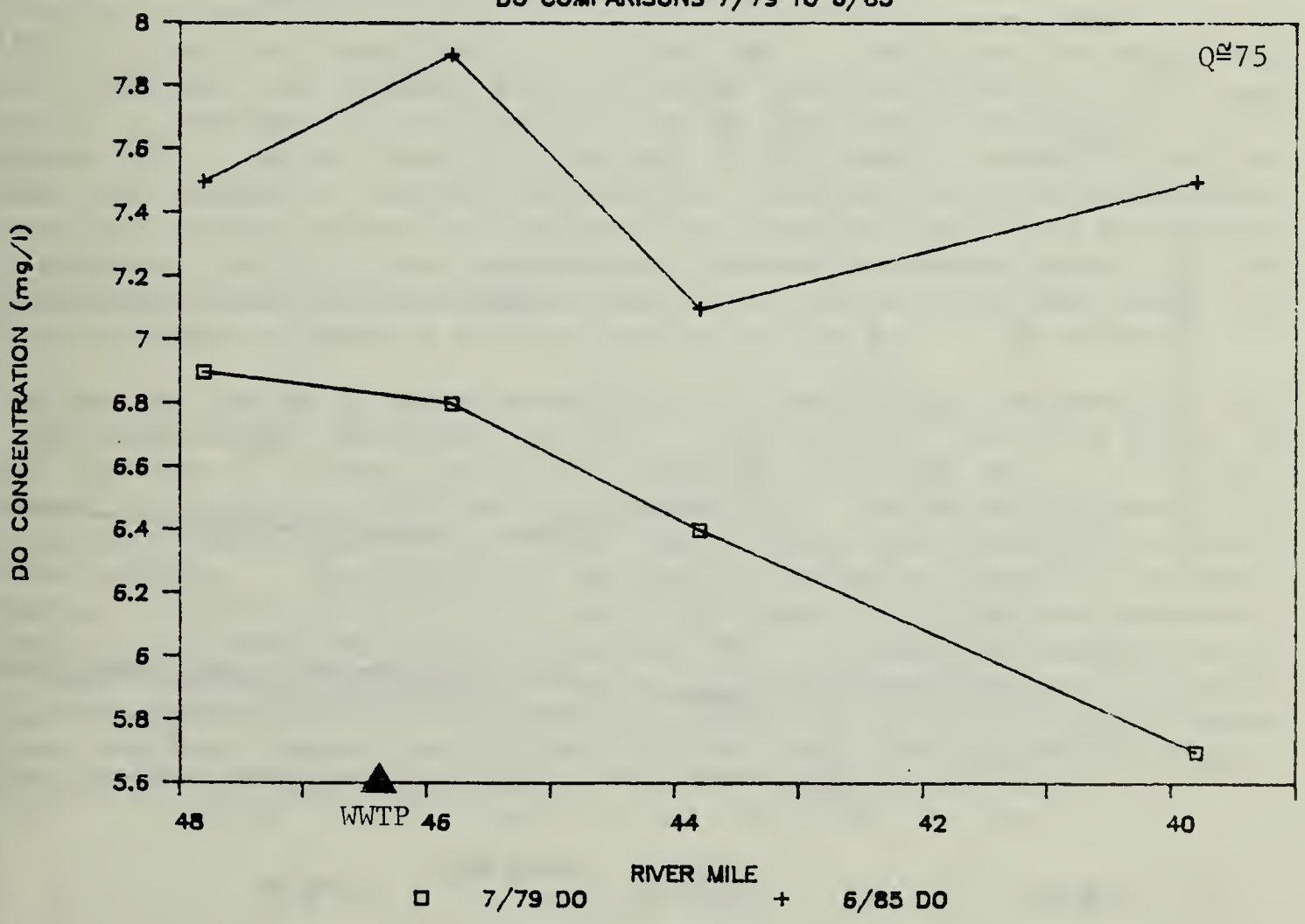


FIGURE 13

NORTH NASHUA RIVER

BOD AND SS COMPARISONS 7/79 TO 6/85

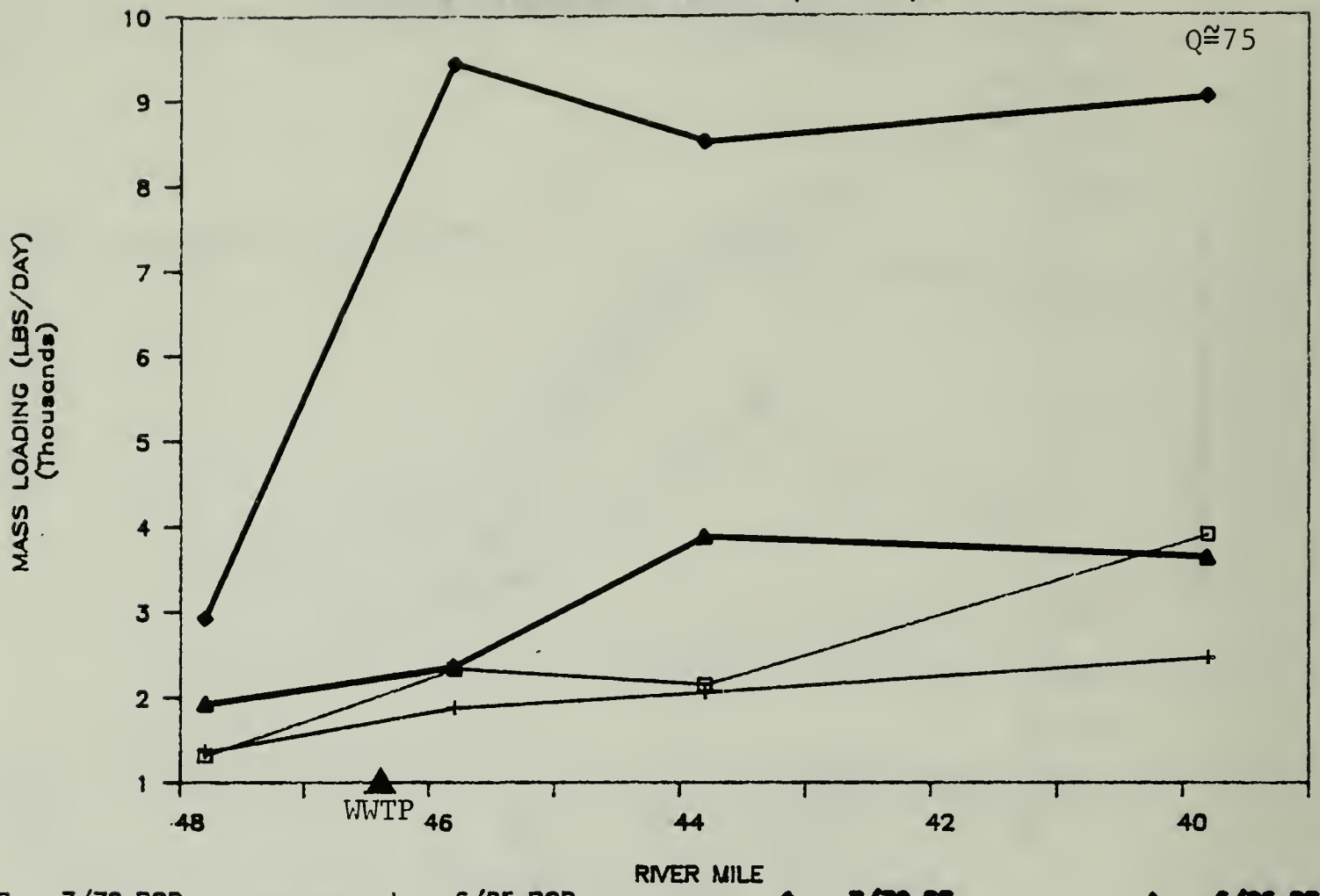
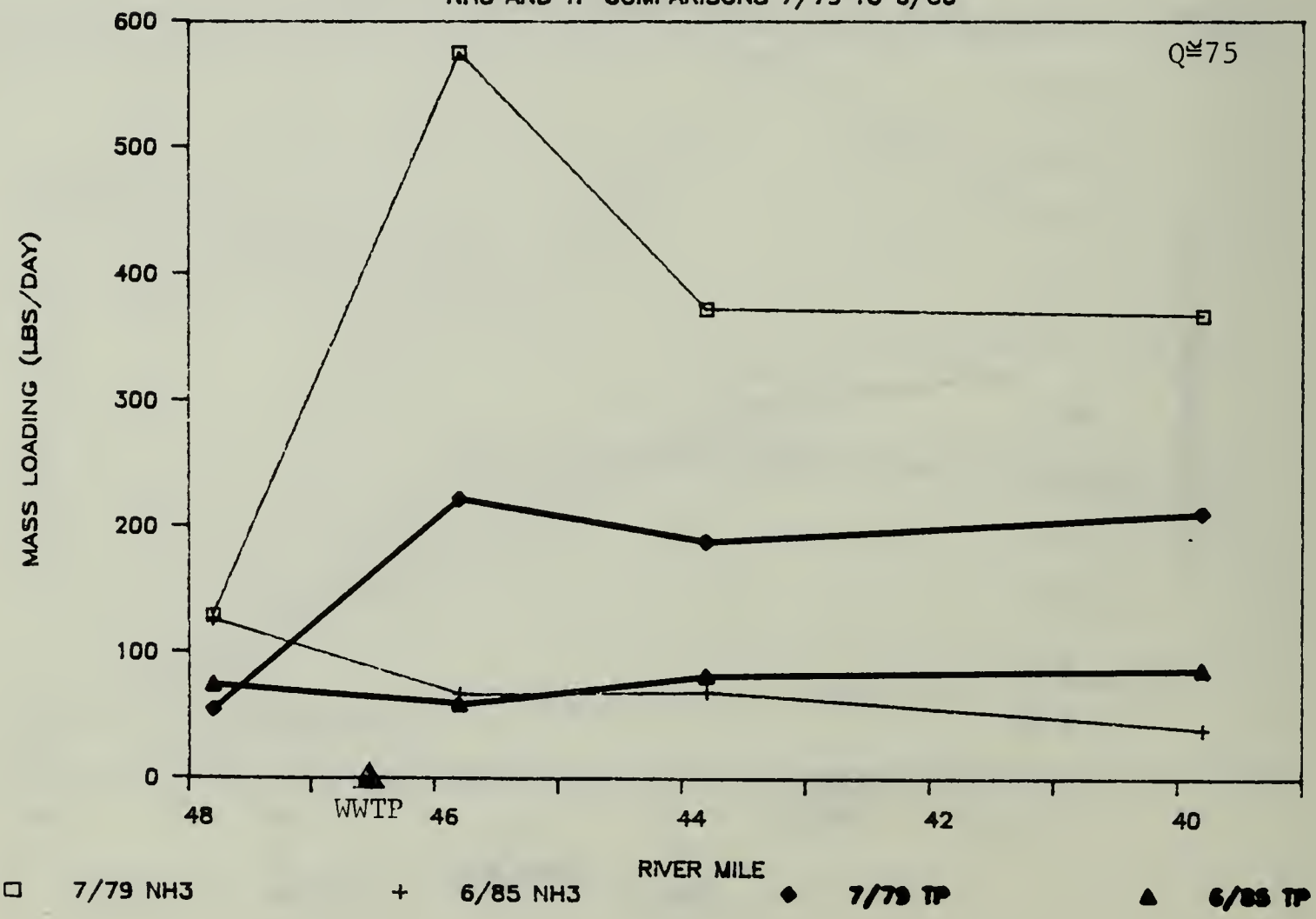


FIGURE 14

NORTH NASHUA RIVER

NH3 AND TP COMPARISONS 7/79 TO 6/85



MANSFIELD WWTP

History

The Mansfield WWTP (NPDES Permit No. MA0101702) previously discharged to Back Bay Brook, in Mansfield, Mass. Back Bay Brook is a small tributary to Norton Reservoir. The outlet of Norton Reservoir is the Rumford River, which flows south until it joins the Wading River and becomes the Threemile River. Sewers in Mansfield were first constructed in the late 1930's and the WWTP was completed in March 1940. Several expansions and additions were added throughout the years. In 1968 the plant was changed to a modified extended aeration plant. In 1972 aerobic digesters replaced old Imhoff tanks and in 1976 mechanical sludge dewatering was installed to replace drying beds. The plant thus was a 1.0 MGD extended aeration facility (4 aeration basins with mechanical aerators and final settling). The plant also had an auxiliary capacity of 0.5 MGD when excess flow was diverted through primary tanks and trickling filters. The trickling filters could not be operated during the winter due to the cold.

The collection system exhibited serious Infiltration/Inflow (I/I) problems which caused the average plant flow to be 1.4 MGD. The plant also received up to 40% of its wastewater from a candy and chocolate manufacturing company. Over 70 % of the Mansfield WWTP's organic load was discharged by this company in batch, shock loads, so pretreatment and detention basins to attenuate the discharge flows have been required.

The Mansfield POTW caused high nutrient concentrations in Back Bay brook, which caused high nutrients and accelerated eutrophication in Norton reservoir. Due to the high organic loading of BOD and ammonia, the brook experienced dissolved oxygen concentrations less than 4.0 mg/l in the middle of the day.

In 1973 the DWPC prohibited all discharges to the brook upstream from Norton Reservoir and allowed sewer hook-ups (>2000 gpd) only if I/I was removed. In October 1975 a facility plan was initiated with completion in September 1976. As of 1976 the town had 117,500 feet of sewer collection systems that served 54 % of the population. The facility plan recommended an expanded upgraded plant to join with the towns of Norton and Foxborough as a regional facility, and recommended a staged construction of 249,500 linear feet of interceptor, lateral sewers and force mains and three new pumping stations, allowing a greater portion of the town to be served.

During the spring of 1980 construction of an advanced WWTP began, and was completed during the summer of 1985. The upgraded plant was built at a new location in Norton, with the discharge to river mile 9.8 of the Threemile River with a 7Q10 low flow of 4.2 cfs. The upgraded plant is a 3.13 MGD activated sludge plant with nitrification and phosphorus removal by alum addition. The new plant was built with extra capacity to treat wastewater from the towns of Norton and Foxborough. In 1988 the Foxborough wastewater was connected to the Mansfield WWTP for treatment, eliminating the former discharge to Robinson Brook. In the future the town of Norton also plans to tie-in to the Mansfield plant. The plant currently takes septage from both towns. The old Mansfield WWTP has been dismantled and is being used as a compost landfill.

The new 3.13 MGD plant has advanced seasonal limits from May 1 to October 31 of 10 mg/l for BOD and SS, and 1 mg/l for NH3. From November 1 through March 30, the limits rise to 30 mg/l for BOD and SS. Year-round limits of 1 mg/l for phosphorus and 6 mg/l for DO also exist.

WWTP Loading

The new plant went into operation in 1985. Ten days of effluent data from before the upgrading were compared to only six days of effluent data from after the new plant went on line. "After upgrading" data were collected only in October 1985 and during a follow-up survey in June and August 1988. Mass loadings were calculated based on the parameter concentrations and effluent flows. Data are tabulated in Tables A-8 and A-9 of Appendix A. The new plant has significantly lower pollutant loads than the old Mansfield plant. The reductions were as follows:

BOD - 93 % Reduction
SS - 97 % Reduction
NH3 - 99 % Reduction
TP - 92 % Reduction

River Loading

Until the summer of 1985 the old Mansfield WWTP discharged to the small tributary Back Bay Brook. There are some water quality data from when the plant was discharging, and only one day of water quality data collected from after the old Mansfield WWTP was eliminated. One day of before and one day of after data are in Table B-5, Appendix B. There are slight improvements in ammonia and phosphorus concentrations, but solids and dissolved oxygen concentrations have not improved much. There is a large wetland between the old plants' discharge and Norton Reservoir where poorly treated wastes formerly settled and left large organic loads in the sediments. It will be many years before the system cleans itself out.

Water quality data have been collected from the Threemile River from before and after the new plant went into operation. Thus mass loading comparisons were made from the Threemile River to document any adverse impacts of the new discharge on the water quality.

Although several water quality surveys were conducted before the plant began discharging to the Threemile River, only one survey was conducted after the new discharge went into effect. A water quality survey conducted in 1984, immediately before the new plant went on line included no instream flow measurements. The two surveys, before and after, that had the most similar instream flow measurements were conducted thirteen years apart in August 5-7, 1975 and August 16-17, 1988. The flows were 9.4 cfs in 1975 and 9.9 cfs in 1988 at the same station at river mile 10.5.

One station from above the plant (river mile 10.5, the plant is at river mile 9.8) and three stations below the discharge (river miles 8.7, 6.6, and 4.2) were compared. The remaining stations flows were estimated from the effluent input and river mile. Mass loading calculations were based on these flows and calculated for each parameter. Loadings are tabulated in Appendix B, and plotted in Figures 15-17.

The new WWTP does not appear to have any effect on the Threemile Rivers water quality. Comparing data that are thirteen years apart actually showed that the water quality improved, but improvements are probably also a result of other upstream improvements. In thirteen years several industrial discharges have either been eliminated or tied into other nearby treatment plants. By visually comparing the 1984 and 1988 instream concentrations (without flow data) there does not appear to be any water quality degradation as a result of the treatment plant. The treatment plant is operating extremely well and it is unlikely it would cause any degradation.

Cost/Benefit

The total cost to completely plan, design and construct a new 3.13 MGD Mansfield WWTP and install 35,000 linear feet of interceptor sewers and a 3740 foot outfall pipe was $31,262,000. This was funded by a federal grant of $23,574,000 (75.4%), a state grant of $4,601,000 (14.7%) and a local share of $3,087,000 (9.9%). The 1981 grants total in 1988 dollars is equivalent to $39,953,000. The cost to construct was $9.83 dollars per gallon or $12.77 dollars per gallon 1988 dollars. This was the most expensive dollar per gallon plant to construct of the ten WWTP's compared. The plant was built entirely from scratch and did not include the reuse of any of the old processes from the former plant. In addition, new interceptor sewers were constructed.

The average pounds per day removed from the new advanced plant was 887. This is removed at a cost of 28.4 lbs/day/million dollars or 22.2 pounds per day per 1988 equivalent million dollars (Appendix C). The plant is currently operating at 34.6% of its 3.13 MGD design capacity. When the pounds per day removed is proportionally adjusted to the full design capacity, a rate of 64.2 pounds per day of pollutants are removed per 1988 equivalent million dollars spent.

The construction of the new plant has caused slight water quality improvements to Back Bay Brook since the discharge was eliminated. Complete recovery from the former discharge will take years. The new discharge location does not appear to be causing any adverse water quality effects to the new location on the Threemile River.

FIGURE 15

THREEMILE RIVER

BOD AND SS COMPARISONS

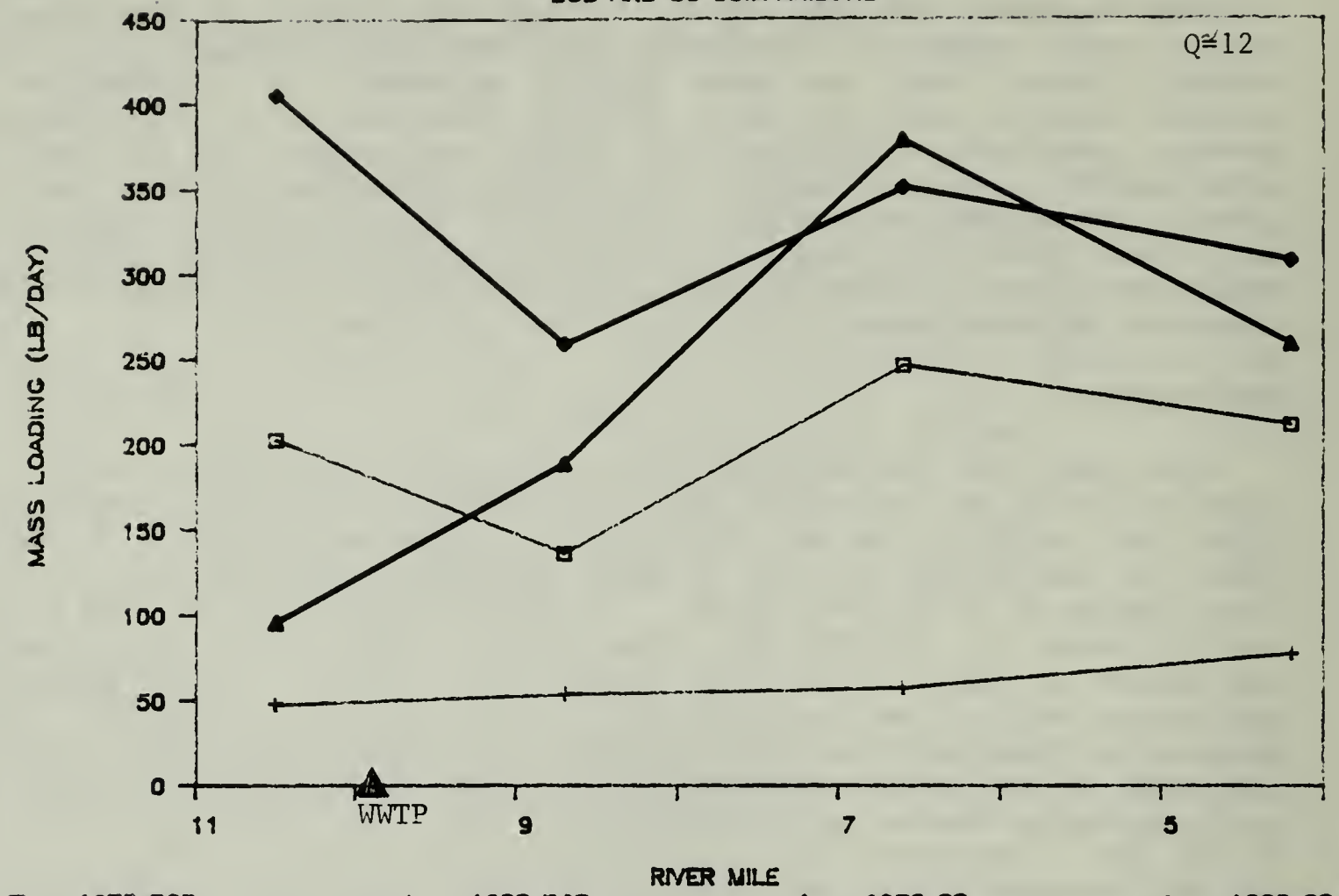


FIGURE 16

THREEMILE RIVER

NH3 AND TP COMPARISONS

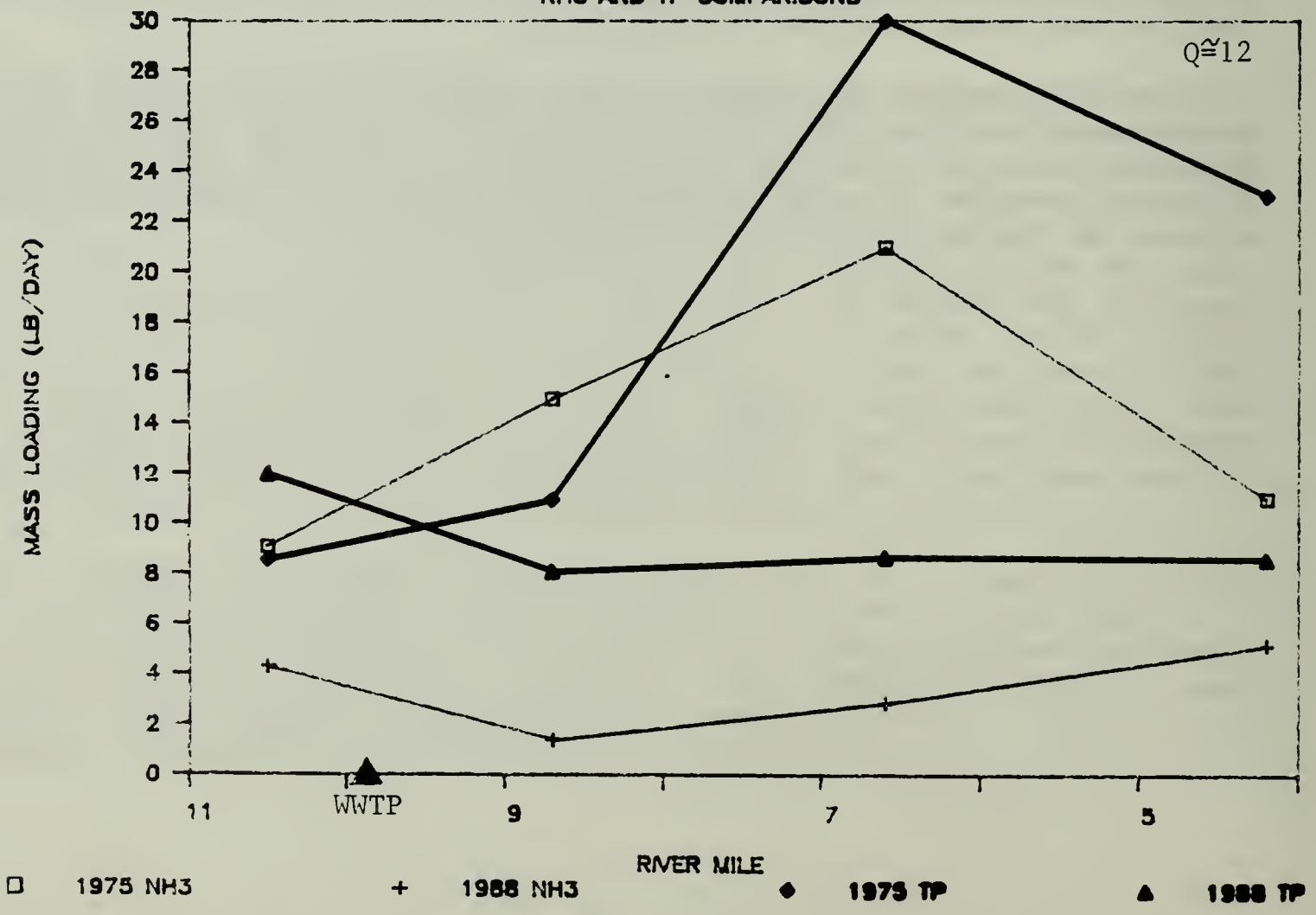
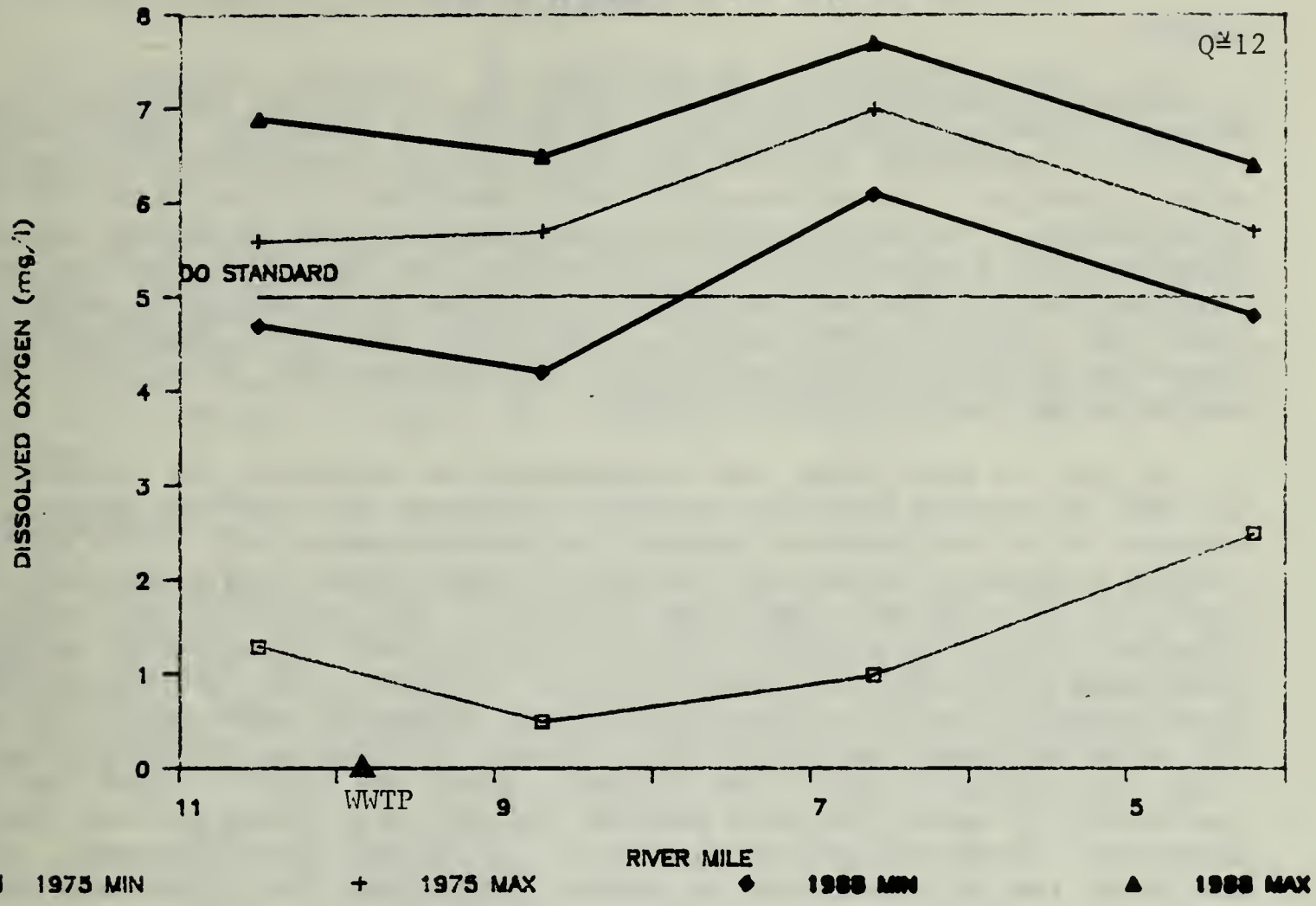


FIGURE 17

THREEMILE RIVER

1975 & 1988 MINIMUM AND MAXIMUM DO'S



MIDDLEBOROUGH WWTP

History

The Middleborough WWTP (NPDES Permit No. MA0101591) discharges to the Nemasket River at river mile 4.8, at a 7Q10 of 2.95 cfs. The plant was initially constructed in 1949 as a 0.75 MGD secondary plant with primary clarification, trickling filter, secondary clarification and chlorination. The water quality of the lower Nemasket River was seriously degraded as a result of the discharge from the Middleborough WWTP. Dissolved oxygen dropped below 2.0 mg/l and high nutrients stimulated algae and aquatic plant growth. The plant was also overloaded by a Cranberry product company which had pH extremes that caused biological upsets in the waste treatment process.

In 1972, a facilities plan recommended the expansion and upgrading of the WWTP to provide advanced secondary treatment and nutrient removal. In February 1974 the Division ordered the Middleborough WWTP to be upgraded and the cranberry company be tied-in. Construction of the upgraded plant began in 1975 and was completed in 1977. The new plant is a 2.5 MGD advanced plant with primary clarification followed by extended aeration, rapid sand filtration and post-aeration. A pilot study during the design phase assumed that the nutrient-deficient cranberry waste would mix with the domestic waste and lower the effluent phosphorus concentration. The study was completed before the cranberry plant was built. Since that time the cranberry waste has been sampled and has been found to have varying phosphorus concentrations ranging from 1 - 25 mg/l of phosphorus. Since the plant has no provisions to remove phosphorus, the phosphorus limits have been temporarily removed from the permit.

The cranberry waste was first connected to the Middleborough plant in 1967 and always had an ongoing problem with low and varied pH concentrations in the wastewater. The low pH and large, rapid pH swings affected the biological activity of the trickling filters and the biological activity in the newly upgraded plant. The company added sodium hydroxide to adjust the pH. However, the waste was very acidic and had no buffering capacity, so the pH adjustment was temporary and the wastewater regained its low pH while traveling to the municipal WWTP.

Eventually, in 1987, the town of Middleborough, EPA and DEQE filed a $2.1 million dollar suit against the cranberry company. After much legal work and discussion, the cranberry company struck a plea bargain with EPA in court, pleading guilty for one fourth of the counts and offering to pay a fine of $400,000. In addition to the fine, the company also provided a belt filter press for solids handling at the Middleborough WWTP and aided in the replacement of the deteriorating force main that transfers the wastewater from the company to the WWTP.

The Middleborough WWTP was also having problems with a high incoming BOD from the company. The cranberry waste contributes 20-30 % of the wastewater flow and 80 + % of the incoming BOD load to the plant. The large volume of BOD caused a nutrient deficiency that resulted in the failure of microorganisms to grow properly and thus not treat the waste adequately. The microorganisms need 100 lbs of BOD to 5 lbs of nitrogen. Without this ratio the waste is not broken down as readily and a viscous

bulking sludge is produced. The sludge does not settle, is difficult to remove, and creates operational problems.

The cranberry company, in addition to controlling their pH more effectively, now also adds urea (a form of nitrogen) to their wastewater. Urea is added based on the companies projected BOD load, to bring the effluent up to a 100:5 : BOD:Nitrogen ratio.

The new Middleborough WWTP has year-round limits of 7.0 mg/l for BOD, SS and DO, and seasonal limits of 1.0 mg/l for NH3 and TP. The WWTP has improved the water quality downstream of the WWTP by reducing the organic loads from ammonia and BOD, and improving the dissolved oxygen. Below the WWTP, however, the Nemasket River flows sluggishly through wetland areas which will continue to impact the dissolved oxygen, even with advanced treatment.

WWTP Loadings

The Middleborough WWTP was upgraded in 1977, and only seven days of effluent data are available from before the plants' upgrading. These were compared to ten days of effluent data from after the plants' upgrading (See Appendix A). Mass loading calculations were made using the plants effluent flow and effluent concentrations. Significant pollutant reductions were observed after the Middleborough plant was upgraded.

BOD - 96 % Reduction
SS - 96 % Reduction
NH3 - 97 % Reduction

The suit with the cranberry company was filed in 1987 and settled in 1988. The new pH and nutrient adjustments at the company have gone into effect only recently, and the benefits may not be reflected in the effluent data tabulated in Appendix A. It is assumed that the wastewater will improve even more once all these steps are taken.

River Loading

Several river surveys have been conducted on the Nemasket River since the Middleborough plant was upgraded, and only a few from before the plant was upgraded. The most recent water quality surveys were conducted during the summer of 1988. Unfortunately the instream flows measured in 1988 were not similar to any of the "before upgrading" surveys. The July 9-10, 1980 survey had similar flows to the August 12-15, 1975 survey. Flows at river mile 5.6 were 21.5 cfs in 1975 and 18 cfs in 1980. The remaining stations flows were estimated from other instream measurements, knowing the WWTP effluent discharge and estimations. Mass loading calculations were based on these flows and the measured instream concentrations.

Four river stations were compared; one from above the WWTP at river mile 5.6 (the WWTP is at river mile 4.8), and three from below the WWTP at river miles 3.7, 2.6, and 0.5. Loadings are tabulated in Appendix B, and plotted in Figures 18 and 19.

Between the 1975 and 1980 water quality surveys, the BOD loadings in the Nemasket River decreased slightly while those for suspended solids and ammonia decreased greatly. The upstream water quality in 1980 was slightly worse than in 1975.

Both minimum and maximum dissolved oxygen concentrations were higher in 1980 than in 1975. The 1980 minimum dissolved oxygen often was within one mg/l of the 1975 maximum dissolved oxygen observed, and just below the 5.0 mg/l standard. The 1988 water quality survey, however, had very low dissolved oxygen concentrations, down to 1.4 mg/l and at concentrations similar to the 1975 survey. The 1988 survey was conducted under flow conditions that were half the flow measured in 1975 and 1980. The downstream sluggish sections and wetlands probably caused the reduced oxygen. Other pollutant loads appeared lower than the 1975 loadings.

Cost/Benefit

The total cost to plan, design and construct the upgraded Middleborough WWTP was $5,943,000. This was funded by a federal grant of $4,399,000 (74 %), a state grant of $880,000 (14.8 %), and local funds of $664,000 (11.2 %). The 1975 total, when converted to an equivalent 1988 dollars total is $12,136,000. The 2.5 MGD plant was upgraded at a cost of $2.38 dollars per gallon or $5.10 dollars per gallon 1988 equivalent dollars.

The upgraded plant has an average removal of 3,297 pounds of BOD, SS, and NH3 per day. This is removed at a cost of 554.7 lbs/day per million dollars or 271.7 lbs/day per 1988 equivalent million dollars (See Appendix C). The plant is currently operating at 36.9% of its 2.5 MGD design capacity. When the pounds per day removed is proportionally adjusted to the full design capacity, a rate of 736.2 pounds per day of pollutants are removed per 1988 equivalent million dollars spent.

The upgraded plant has had beneficial effects on the ammonia removal, causing elevated instream dissolved oxygen concentrations during the 1980 survey.

FIGURE 18

NEMASKET RIVER

BOD AND NH3 LOADING COMPARISONS

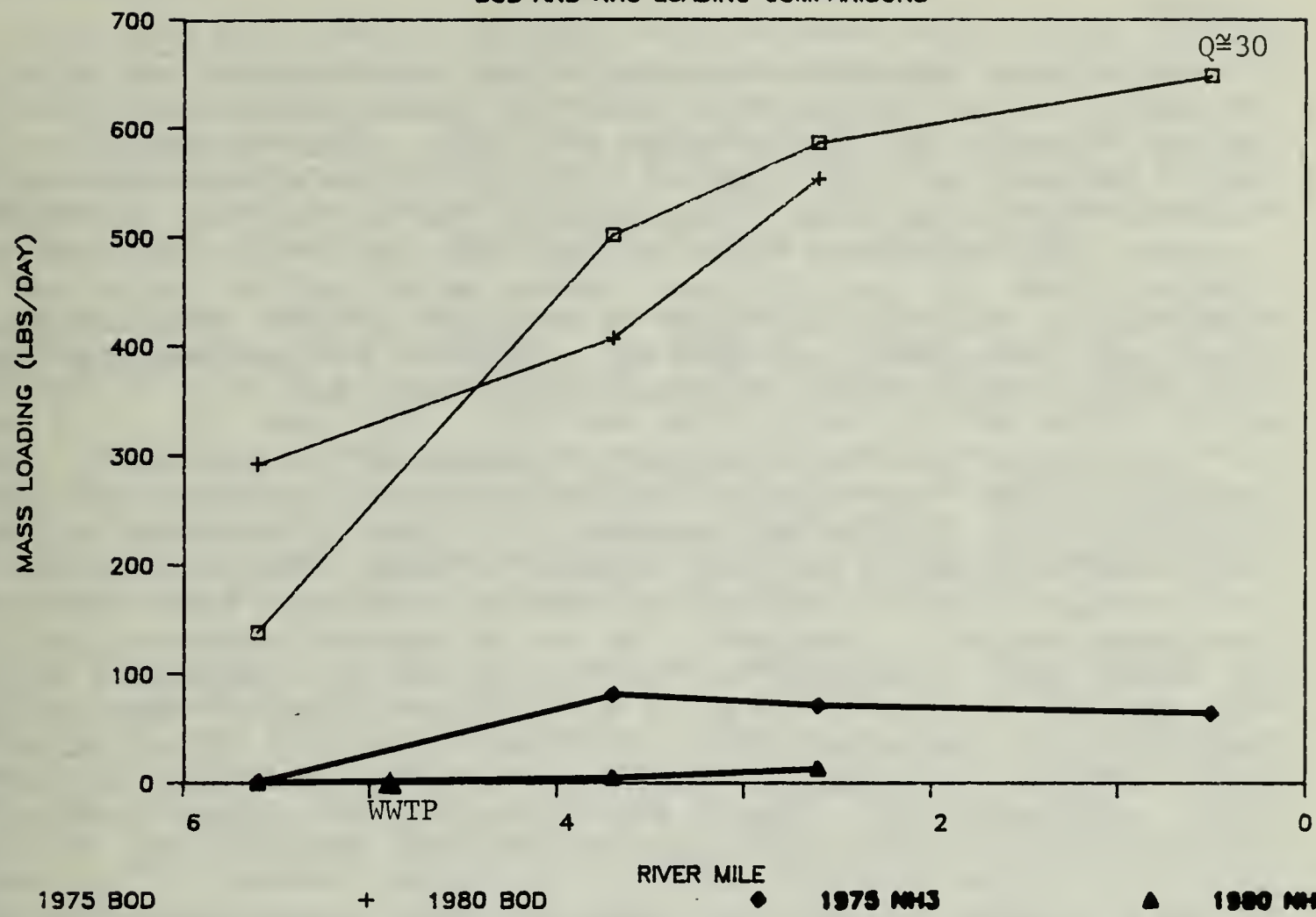
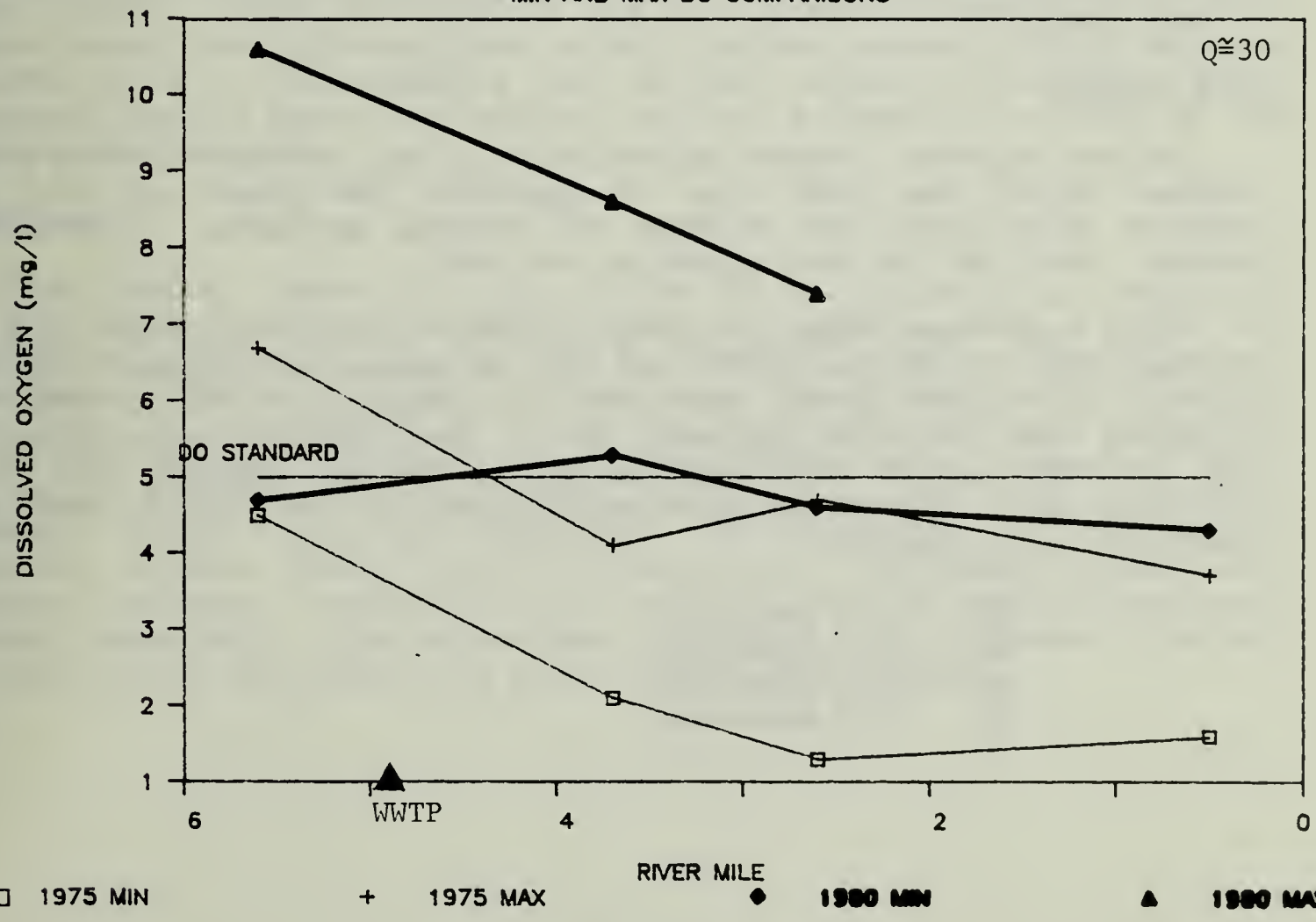


FIGURE 19

NEMASKET RIVER

MIN AND MAX DO COMPARISONS



MILFORD WWTP

History

The Milford Wastewater Treatment Plant (NPDES Permit No. MA0100579) discharges to the Charles River near its headwaters at river mile 73.4. At this location the Charles River is a small narrow stream with a seven day - ten year low flow (7Q10) of 0.72 cfs. Three miles downstream from the WWTP the Charles River is impounded by the Box Pond Dam. Box Pond is a one-mile long impoundment with sluggish flows. Due to the low flows of the Charles River and low dilution, severe water quality violations were occurring in the Charles River as a result of the treatment plant's discharge. Downstream, Box Pond was acting as a final settling lagoon, resulting in algae blooms and dense aquatic vegetation.

The Milford WWTP was originally constructed in 1908 as a 4.0 MGD secondary plant. The treatment consisted of trickling filters followed by clarifiers and chlorine disinfection. In 1973 a Wasteload Allocation (WLA) was performed by the DEQE Division of Water Pollution Control. The WLA recommended strict advanced wastewater limits with nitrification and phosphorus removal. Construction of the new upgraded advanced plant began in August 1983. The plant went on line in the fall (September) of 1986. The upgraded Milford WWTP is a 4.3 MGD advanced wastewater treatment plant consisting of headworks, primary clarifiers, trickling filters, alum and lime addition, intermediate clarifiers, rotating biological contactors, final clarifiers, sand filters and ultraviolet (UV) light disinfection, before being discharged with step aeration to the Charles River.

As a secondary plant, the conventional NPDES permit limits were for 30 mg/l BOD5 and 30 mg/l SS. As an advanced plant the NPDES permit requires seasonal monthly average limits from April 15 through November 15 of 7.0 mg/l for BOD and SS and 1.0 mg/l for NH3 and TP. During the winter, BOD and SS limits are raised to 30 mg/l. A dissolved oxygen limit of 6.0 mg/l is also required.

WWTP Loading

The new upgraded advanced Milford WWTP is well within its NPDES permit limits. During the first year of operation the plant ran into some problems with electrical failures and process shutdowns. Since then, however, the plant has been operating very well.

There have been numerous water quality samples collected from the Charles River and Milford WWTP. Ten days of wastewater effluent data from before the upgrading and ten days of effluent data from after the upgrading were tabulated (Appendix A) . Mass loading calculations for BOD, SS, NH3 and TP were made using the average effluent flow. The following pollutant reductions were observed at the Milford WWTP as a result of the upgrading:

BOD - 84 % Reduction
SS - 85 % Reduction
NH3 - 95 % Reduction
TP - 93 % Reduction

River Loadings

There have been numerous synoptic and intensive water quality surveys conducted on the Upper Charles River to monitor the impact from the Milford WWTP. In 1988 a year of monthly surveys were conducted to monitor the newly upgraded WWTP. The two surveys which had the most similar instream flows, water temperatures and climate conditions were the surveys conducted on August 6, 1986 and August 4, 1988. The two comparable flows at river mile 73.0 were 8.8 cfs on 8/6/86 and 8.3 cfs on 8/4/88.

Both surveys sampled the same water quality stations. Comparisons were made between four stations; one station located upstream of the discharge at mile 73.9 and three stations downstream of the discharge at miles 73.0, 72.0 and 70.3. The last station was at the outlet of Box Pond. The Milford WWTP discharges to the Charles River at river mile 73.4. Flow values at the remaining three stations were estimated, based on the effluent flow and drainage areas. Mass loading calculations for each parameter at each station were based on these flows. The mass loading comparisons are tabulated in Appendix B and graphed in Figures 20-22.

The data indicates significant instream reductions in BOD, ammonia and phosphorus loadings and no reductions in suspended solids loadings. The water quality at the upstream station (river mile 73.9) was noticeably worse in 1988 than in 1986. There are upstream pollutant discharges that were not corrected with the upgrading of the treatment plant. When comparing the instream dissolved oxygen concentrations, this was very apparent. The upstream station had a minimum dissolved oxygen of 2.0 mg/l during both surveys. Below the WWTP discharge the instream minimum dissolved oxygen was still low, but improved over the earlier data. At the Box Pond dam, (river mile 70.3) the dissolved oxygen in August 1988 had a minimum concentration of 5.3 mg/l, slightly above the water quality standard requirement of 5.0 mg/l. The pond still had excessive plant and algae growth. High nutrients in the pond causing algae and dissolved oxygen variations could continue to be a problem because of high nutrient concentrations in the sediment, and the poor upstream conditions. The treatment plant's upgrading, however, has had a beneficial effect on the rivers water quality.

Cost/Benefit

The planning, design and construction for the upgrading and expansion of Milford's existing wastewater treatment facility cost a total of $19,201,000 dollars. Of this $19,016,000 was eligible for financial assistance. The total cost was funded by a federal grant of $14,262,000 (74.3 %), a state grant of $2,852,000 (14.9 %) and local funds of $2,087,000 (10.9 %). Originally the federal grants were to cover 75 % of the share, the state was to provide 15 % and the local share was 10 %. However, since the plant contained new innovative and alternative treatment options (RBC's and UV disinfection), the federal grants for certain costs were increased an additional 10 %, and the state grants were reduced accordingly. The grants were awarded in 1983, and when converted to 1988 dollars translates to a total cost of $21,371,000.

The cost per gallon to construct the 4.3 MGD plant was $4.47 dollars per gallon, or $4.78 1988 dollars per gallon. The upgraded plant removes an average of 1,388 pounds per day of BOD, SS, NH3 and TP (Appendix C, Table C-6). This load is removed at a rate of 72.3 lbs/day per million or 64.9 lbs/day per 1988 million. The plant is currently operating at 73.9% of its design capacity. When the pounds per day removed is proportionally adjusted to the full design capacity, a rate of 88.0 pounds per day of pollutants are removed per 1988 equivalent million dollars spent.

The $19 million that was spent has led to instream nutrient loading reduction of 97 % or greater for the first three miles below the WWTP. The instream dissolved oxygen concentrations have improved, with the achievement of water quality standards within Box Pond. Upstream discharges currently cause a problem with the instream water quality, but with their elimination water quality standards should definitely be met.

FIGURE 20

CHARLES RIVER

BOD AND SS LOADING COMPARISONS

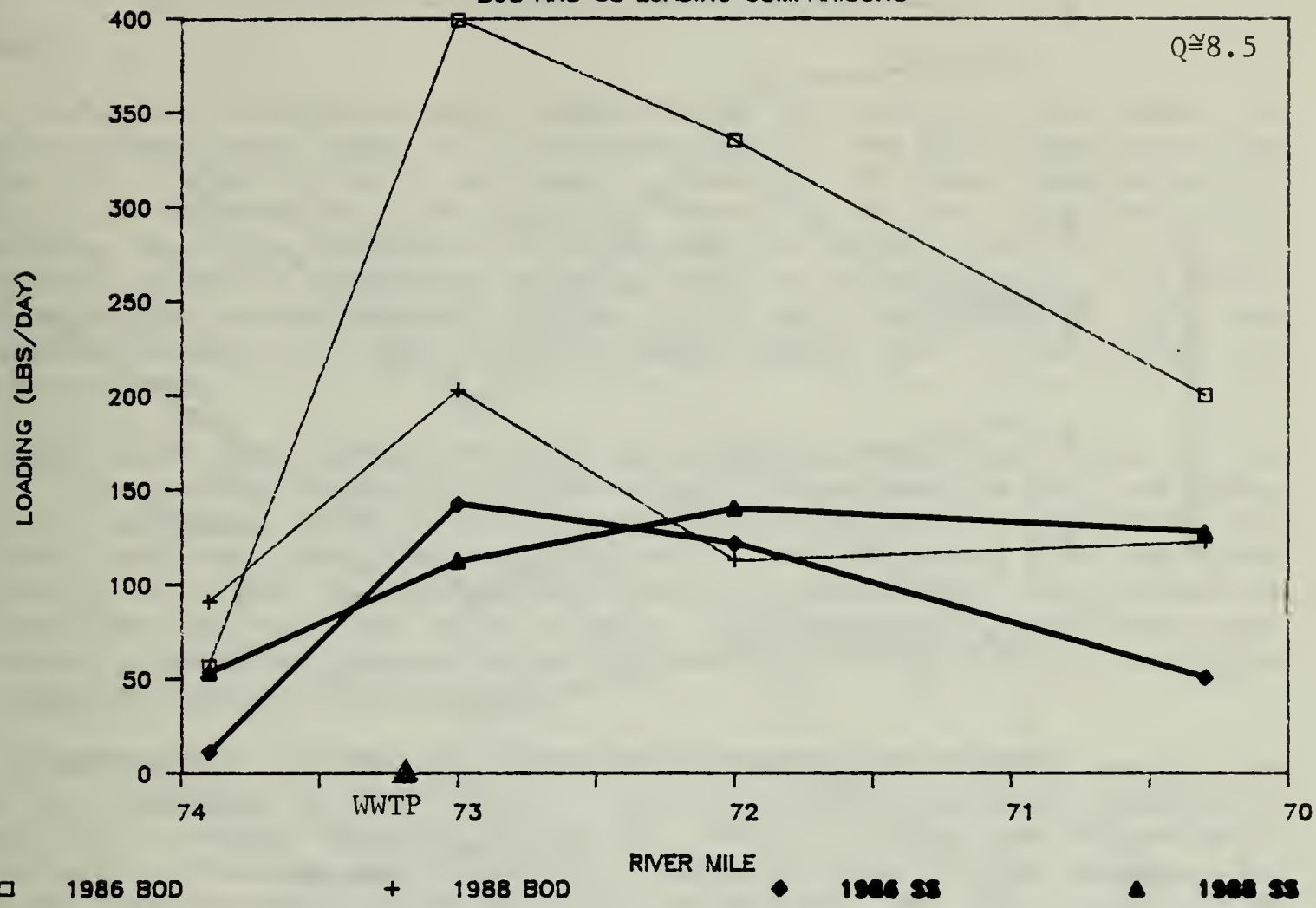


FIGURE 21

CHARLES RIVER

NH3 AND TP LOADING COMPARISONS

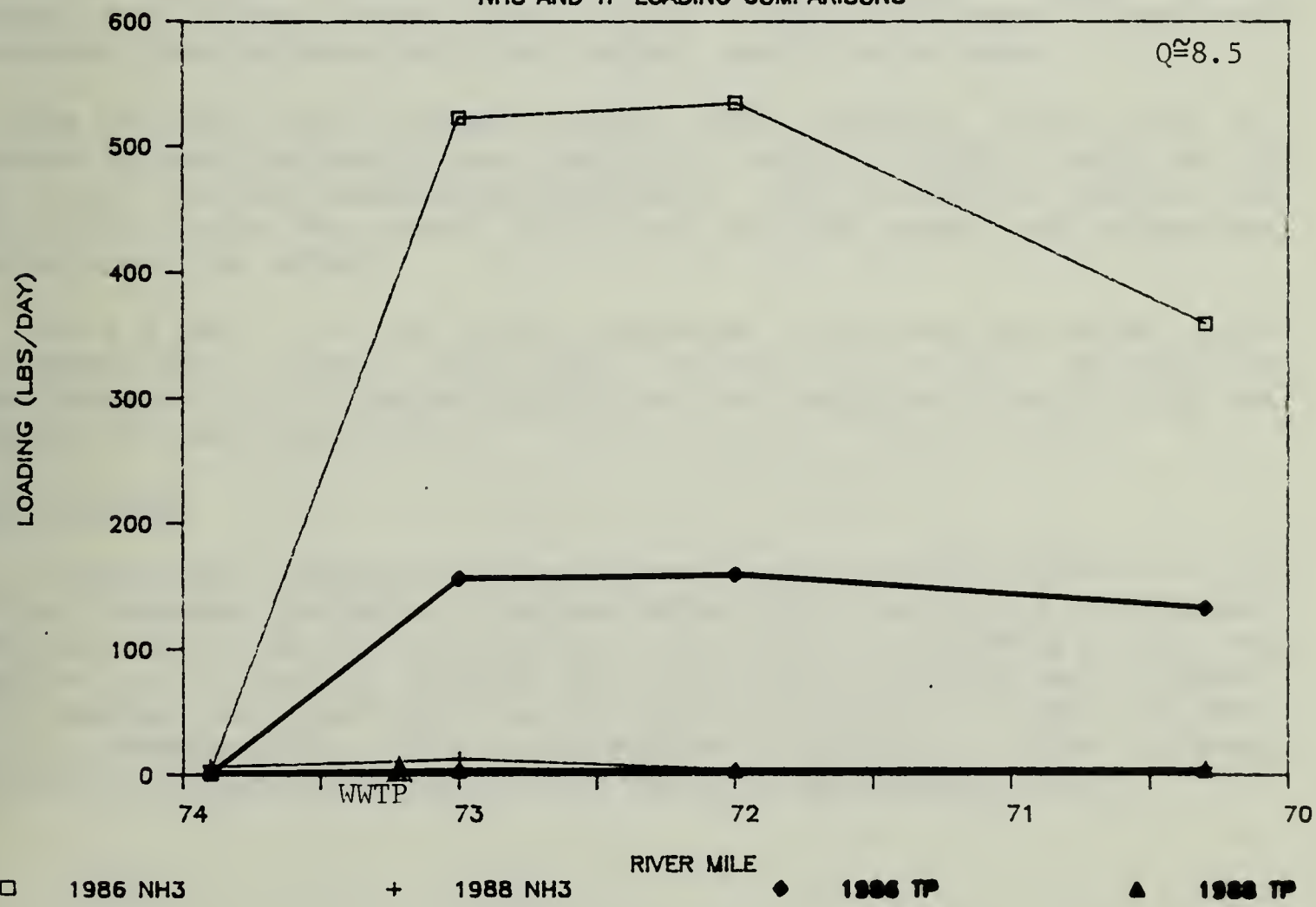
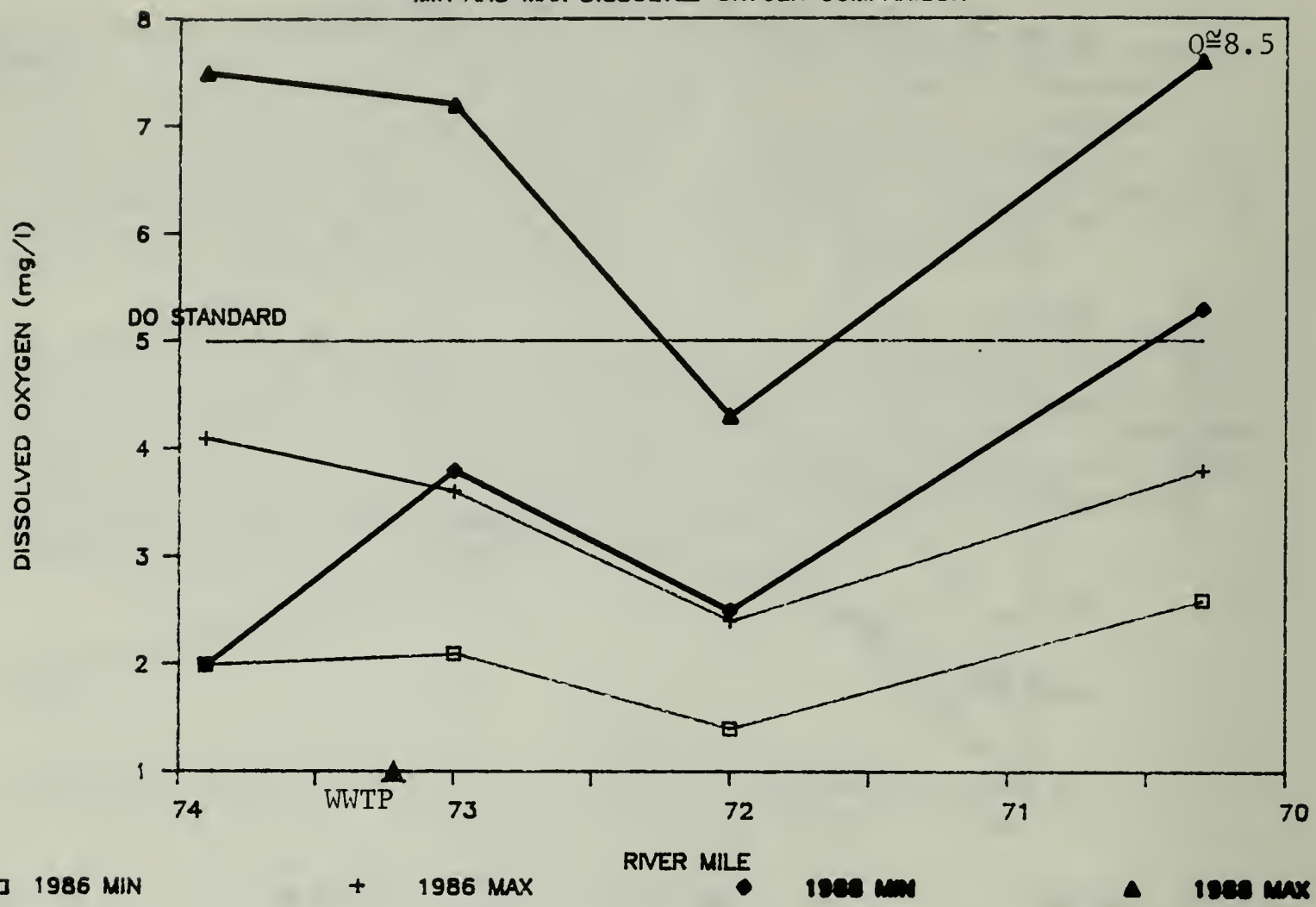


FIGURE 22

CHARLES RIVER

MIN AND MAX DISSOLVED OXYGEN COMPARISON



NORTH ATTLEBOROUGH WWTP

History

The North Attleborough WWTP (NPDES Permit No. MA0101036) is located in North Attleborough, Mass and discharges to the Ten Mile River at river mile 15.4. The cities first sewer system and WWTP was constructed in 1906, with improvements and upgrading occurring in 1946 and 1959. This secondary facility consisted of headworks, a primary settling tank, a trickling filter, a secondary settling tank and chlorination. The plant had secondary average monthly limits of 55 mg/l for BOD5, 25 mg/l for suspended solids, 0.1 ml/l for settleable solids and 200 org/100ml for fecal coliform.

The plant had a design capacity of 1.2 MGD and an average flow of 2.9 MGD. The plants' trickling filter could not accommodate all the extra flow so wastewater often bypassed the trickling filters, passing from the primary settling tank to the sand filters. The overloaded WWTP was above capacity and was causing water quality degradation and standards violations in the Ten Mile River. Environmental consultants were eventually hired to evaluate expanding the plants' capacity and to design an upgraded, more efficient plant.

Construction of a new upgraded and expanded plant began in early 1978 and was completed in March 1980. The new two-stage advanced wastewater plant had a design capacity of 4.6 MGD. The two stages are mechanically mixed air activated sludge systems, with the first stage designed to remove carbonaceous oxygen-demanding substances and the second stage designed to convert nitrogen compounds to nitrate (nitrification). The plant is only at about 50 % capacity, and only the second stage is used to meet permit limits. Thus the plant does not use the first stage during the summer months, but rather runs in a modified extended aeration mode. During the winter, with more lenient limits and larger flows, the treatment plant is operated in the contact stabilization mode.

The new plant has seasonal advanced NPDES effluent limits. From May through October the permit has limits of 5 mg/l for BOD5, 7 mg/l for SS and 1 mg/l for both ammonia and phosphorus. For the rest of the year the BOD and SS limits are raised to 15 mg/l and the ammonia and phosphorus limits are not in effect.

The 4.6 MGD (7.15 cfs) plant discharges to the Ten Mile River where the stream has a 7 day 10 year (7Q10) low flow of 0.47 cfs. The effluent thus receives a 1:16 dilution during low flow conditions, contributing the majority of the stream's flow.

WWTP Loadings

Significant reductions in pollutant loading were observed in the effluent between the before data and after data. Seven days of effluent data from before the WWTP was upgraded (all that are available at TSB) was compared to 10 days of effluent data from after the WWTP was upgraded. Mass loadings were calculated using effluent flow data and BOD, SS, NH3, and TP concentrations. Data are tabulated in Appendix A. The following pollutant reductions were observed at the North Attleborough WWTP:

BOD - 86.5 % Reduction
SS - 92 % Reduction
NH3 - 69 % Reduction
TP - 62.5 % Reduction

River Loadings

Water quality data was collected from the Ten Mile River during surveys run in July and September 1973, June and August 1981, and June, July, August and September 1984. The 1973 surveys were conducted before the WWTP was upgraded and the 1981 and 1984 surveys were conducted after the WWTP was upgraded. No instream flow measurements were made during the 1981 surveys so mass loading calculations or comparisons could not be made between the 1981 and other surveys. Comparisons were thus made between the 1973 and 1984 surveys. The two surveys which had the most similar flows were the July 4-5, 1973 and July 24-25, 1984 surveys. Flow at mile 15.6 was 12.9 cfs in 1973 and 10.2 cfs in 1984.

The two surveys did not include identical sampling locations. In 1973 samples were taken from river miles 15.6, 15.2, 14.2, and 12.6 (The WWTP is at river mile 15.4). During the 1984 survey, samples were collected from river miles 15.6, 14.2, 13.4, 13.0, and 12.6. Flow estimates were made at the remaining stations using other known flow measurements, known discharge flows and drainage areas. The mass loadings for each pollutant were then calculated at each river mile. The before and after loadings for each parameter (at each station) are tabulated in Appendix B, and plotted in Figures 23 through 25.

In general, there were large decreases in loadings for SS, NH3, and TP and moderate reductions for BOD. The upstream water quality was much better in 1984, possibly contributing to some of the large differences between the surveys. The dissolved oxygen, however, also had increased significantly, indicating the decreased instream pollutant loadings are improving the water quality in the Ten Mile River. Both the minimum and maximum dissolved oxygen concentrations were higher downstream from the WWTP discharge. Upstream concentrations were fairly similar, but in 1973 the minimum dissolved oxygen sagged to a low of 3.6 mg/l three miles below the plant discharge. In 1984 the lowest dissolved oxygen was 5 mg/l three miles below the discharge, a concentration meeting water quality standards, and 1.4 mg/l higher than in 1973.

Cost/Benefit

The total cost to plan, design and construct the upgraded and expanded North Attleborough WWTP and to install regional interceptors, collector sewers and one pumping station was $17,079,000. The cost was funded by a $12,436,000 (72.8 %) grant from the federal government, a $2,487,000 (14.6 %) grant from the state and a total of $2,156,000 (12.6 %) from local shares with $1.6 million coming from the town of North Attleborough and $0.6 million from the town of Plainville (which also is serviced by the plant). When the 1978 money is converted to 1988 money, the equivalent cost is $27,770,000.

The plant has a design capacity of 4.6 MGD which translates to a cost/gallon of $3.71 or a 1988 equivalent cost/gallon of $6.04. The upgraded plant removes an average of 2,110 pounds per day of BOD, SS, NH3 and TP (See Appendix C, Table C-7). The cost to remove these pounds per day is 123.6 lbs/day removed per million (original costs), or 76.0 lbs/day removed per 1988 equivalent million dollars. The plant is currently operating at 81.2% of its 4.6 MGD design capacity. When the pounds per day removed is proportionally adjusted to the full design capacity, a rate of 93.6 pounds per day of pollutants are removed per 1988 million dollars spent.

In addition to the large pollutant reductions in the effluent the cost to upgrade the WWTP also had beneficial effects on the instream water quality. The minimum dissolved oxygen below the upgraded plant was greater than 5.0 mg/l, the rivers class B water quality standard requirements.

FIGURE 23

TEN MILE RIVER

BOD & SS COMPARISONS – N ATTLEBORO WWTP

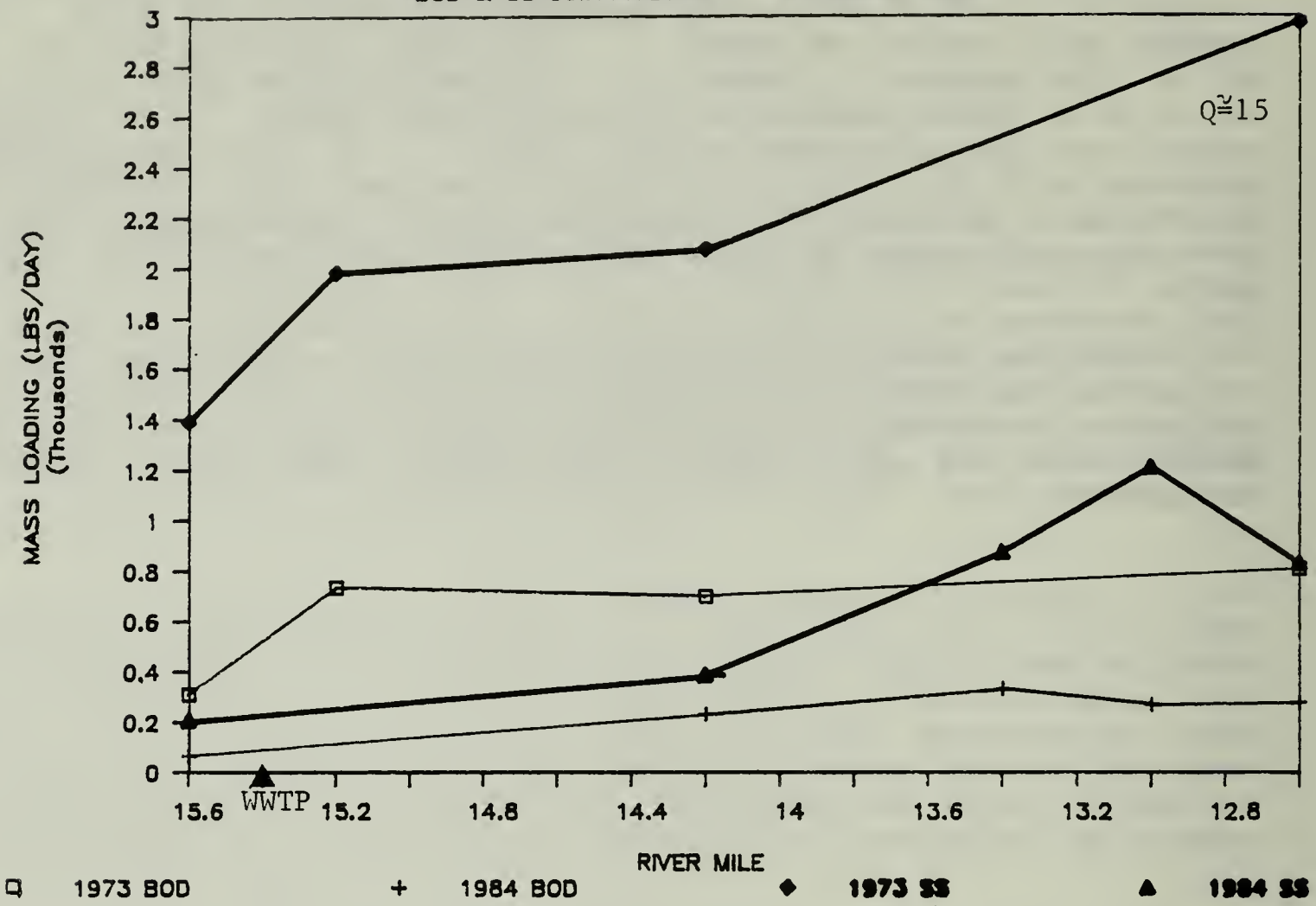


FIGURE 24

TEN MILE RIVER

NH3 & TP COMPARISONS – N ATTLEBORO WWTP

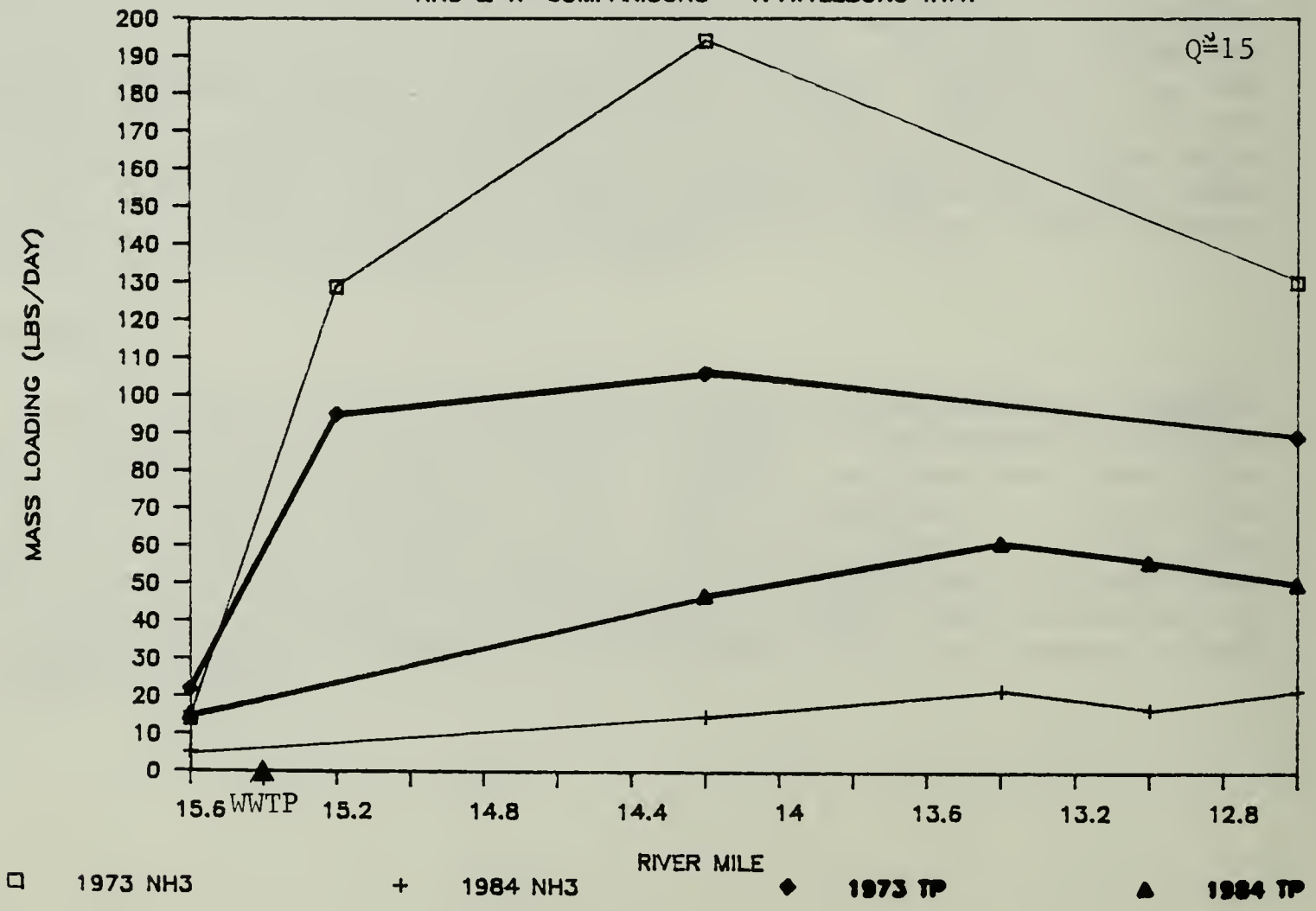
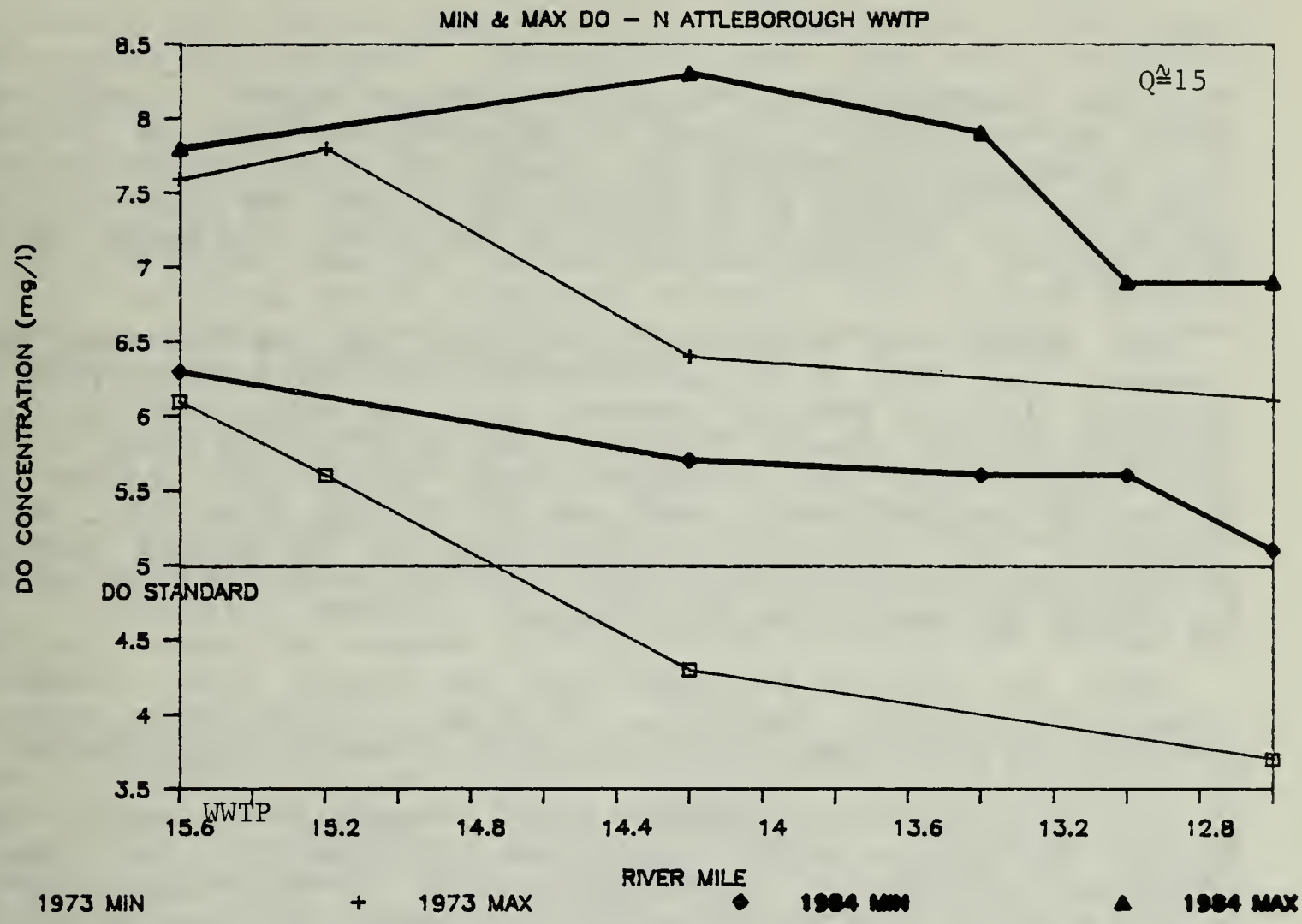


FIGURE 25

TEN MILE RIVER



UPPER BLACKSTONE WPAD

History

The Upper Blackstone Water Pollution Abatement District (UBWPAD)(NPDES Permit No. MA0102369) discharges to the Blackstone River at river mile 46.7 in Millbury. The UBWPAD has a design flow of 56 MGD (86.8 cfs) and discharges to the river at a location with a 7Q10, low flow of 7.9 cfs. The wastewater contributes up to 92% of the rivers flow during low flow conditions.

The UBWPAD was originally constructed as the Worcester Sewage Treatment Plant (STP) in the early 1900's as a 30 MGD secondary plant with trickling filters. When the treatment plant was constructed the city of Worcester was also sewered. Approximately 70 of the 315 miles of sewers were combined sewer and stormwater lines. During storm events, large amounts of combined sewage overflowed to the Mill Brook Canal and the remaining flow increased the overloading of the already overloaded Worcester plant. The Mill Brook Canal, in addition to CSO overflows, also had illegal dry weather sewage discharges.

While the STP was overloaded with wet weather flows it was also affected by industrial discharges. High metal concentrations discharged by industries often caused biological upsets in the trickling filters.

The Worcester STP's effluent severely degraded the rivers' water quality causing high organic loading and nitrification in the river and downstream impoundments. The Blackstone River is first impacted at mile 48.0 by the Mill Brook Canals raw untreated sewage discharges and combined sewer overflows. Next, the river is impacted at river mile 46.7 by the Worcester STP. The canal discharge caused dramatic increases in BOD, SS, NH3, TP and coliform bacteria. Below the STP slight increases in BOD and SS occurred while NH3 and TP concentrations more than doubled. Dissolved oxygen decreased to concentrations below 2.0 mg/l. Ammonia-nitrogen concentrations increased as organic nitrogen was converted to ammonia. Problems were accented because the STP, a major waste source, discharges to the Blackstone River near the headwaters, where the river is least able to assimilate the wastes.

In the early 1970's, the Upper Blackstone Water Pollution Abatement District was formed by the city of Worcester and the towns of Auburn, Leicester, Paxton, Rutland, Holden, Boylston, West Boylston, Shrewsbury and Millbury. The district created a board and was responsible for the construction of a large regional wastewater facility located in Millbury, Mass. and referred to as the Upper Blackstone Water Pollution Abatement District (UBWPAD) facility. Three of these towns have their own wastewater treatment plants, two are treated at the UBWPAD and the remaining have individual septic systems. Small amounts of wastewater from each town, however, is treated at the new plant. Membership in the district allows the towns to have their wastewater treated at the UBWPAD. The majority of the wastewater is from the city of Worcester and the town of Auburn.

During the winter of 1973, at the site of the Worcester STP, construction began on the UBWPAD facility, a 56 MGD activated sludge plant with aerated grit chambers. The secondary plant went into operation in August 1976. Along with the upgrading, many industries (33) which had previously discharged to the river, tied into the UBWPAD sewer network with pretreatment. The new WWTP was operating very well, was below the design flow, and was meeting its secondary NPDES permit limits. The plant even handled upsets from illegal dischargers and industries. The problem of little dilution water and low assimilative capacity at the headwaters of the Blackstone River continued to cause water quality problems instream. Large ammonia-nitrogen loads were causing instream nitrification and a dissolved oxygen sag.

In 1985 the NPDES permit came up for renewal. At this time the permit was revised to include advanced wastewater limits of 10 mg/l for BOD and SS, 2.0 mg/l for ammonia and 6.0 mg/l for dissolved oxygen. The wastewater facility was below design capacity, and with the inclusion of a chemical addition system to raise the alkalinity of the wastewater for the nitrification process, the advanced limits could be met. A state-only grant was awarded to help provide money for the changes and upgrading.

Furthermore, a stormwater treatment facility was constructed during a sewer rehabilitation project in 1987. The project included separation of stormwater and domestic sewers and a stormwater treatment facility. The facility has the capacity to treat 108 million gallons per day of wastewater and is operated by a computerized control system that monitors the flow rate in the collection network. The excess flows that cannot be transported to the treatment plant would be diverted to the stormwater treatment facility for solids removal and chlorination. The primary treated water then is discharged to the Blackstone River at river mile 48.0 (just upstream from the WWTP).

WWTP Loading

Since the revised permit limits went into effect in 1988, only four days of effluent data have been collected in conjuction with two water quality surveys. These four days were compared to ten days of data collected after the initial upgrading and three days of data from before the plant was upgraded and rebuilt as the UBWPAD. Mass loading calculations were made for all three plant operations (See Tables A-15 to A-17, Appendix A). The following pollutant reductions were noted at the Upper Blackstone WPAD between the time when the plant was the Worcester STP and the time it was converted to an advanced wastewater treatment plant:

BOD - 93.6 % Reduction
SS - 92.4 % Reduction
NH3 - 92.7 % Reduction
TP - 43.6 % Reduction

The UBWPAD does not have phosphorus limits, but the plant is receiving such a high level of treatment that the phosphorus concentrations have been reduced considerably. Initially, phosphorus removal was planned, but due to the high concentrations of phosphorus in the river upstream from the WWTP discharge, phosphorus removal has not yet been required.

River Loading

Two water quality surveys were conducted on the Blackstone River during June and August of 1988 to monitor improvements resulting from the advanced permit limits. The June 14, 1988 survey was compared to the June 19, 1985 survey since they were conducted at similar flows and water temperatures. Similarly, the June 19, 1973 survey conducted before the UBWPAD was constructed exhibited similar flows and instream conditions to the other two June surveys. Instream flow measurements were made during the three surveys at river mile 47.9. In 1973 the flow was 51 cfs, in 1985 the flow was 51 cfs, and in 1988 the flow was 43 cfs. These were taken at the station just upstream of the WWTP discharge. In 1985 and 1988 the STP was discharging 37.2 cfs and 50 cfs respectively, so the downstream stations exhibited very similar flows for loading comparisons. The effluent was receiving approximately a 1:1 dilution.

Five instream stations were compared; one upstream of the Mill Brook Canal discharge and one from above the UBWPAD discharge at river miles 51.3 and 47.9, respectively (Mill Brook Canal enters at mile 48.0 and the WWTP is at river mile 46.7). The three remaining stations were located below the UBWPAD discharge at river miles 46.0, 43.6, and 42.2. Between the 1973 and 1985 surveys, significant BOD and SS loading reductions were observed, and a slight dissolved oxygen increase corresponded with the organic loading reduction. Between 1985 and 1988, in addition to the stricter NPDES limits, several CSO's and sewer rehabilitation projects and the construction of the detention facility reduced the pollutant loadings to Mill Brook. These reductions improved the water quality in the Blackstone River above the UBWPAD's discharge. The major improvements, however, were in the instream ammonia and phosphorus loading reductions. The SS loadings actually increased to concentrations much greater than observed in 1985. Dissolved oxygen concentrations also increased downstream from the discharge. The maximum dissolved oxygen in 1988 was similar to the maximum dissolved oxygen observed in 1985. The minimum dissolved oxygen, however, had an increase, raising the minimum oxygen concentration from an average of 4.1 mg/l to 5.0 mg/l immediately below the WWTP discharge. Further downstream the minimum dissolved oxygen increased in 1988, while in 1985 it continued to decrease. Data are tabulated in Appendix B and plotted in Figures 26-28.

Cost/Benefit

The cost to construct the UBWPAD is broken into two parts: the cost to construct the original 56 MGD secondary plant, and the cost for the chemical additions for the nitrification. The plant was built in the early 1970's when construction costs were much lower. The total cost for the planning, design and construction of the 56 MGD secondary plant was $23,341,000. This was paid for by federal grants of $17,446,000 (74.7%), state grants of $3,495,000 (15%) and local monies of $2,400,000 (10.3%).

The new permit limits required nitrification so in 1986 the plant received a 90 % state-only grant to help pay for chemical addition equipment. Sodium carbonate is added to increase the wastewaters alkalinity for the nitrification process. The cost of the nitrification equipment was $323,000, of which $283,500 was paid for by state grants and $39,500 was covered by local funds. Thus, the total cost for the advanced secondary plant with nitrification was $23,664,000. This is equivalent to $52,529,000 dollars in 1988 money. At a total capacity of 56 MGD, the cost is broken down to $0.42 dollars/gallon (original cost) for treatment, or $0.94 dollars/gallon 1988 money.

The upgrading of the plant has resulted in an average of 27,876 pounds per day of BOD, SS, and NH3 removed from the effluent. This is 1,178.1 lbs/day removed per million dollars, or 530.7 lbs/day removed per 1988 equivalent dollars (See Appendix C). The plant is currently operating at 56.5% of its design capacity. When the pounds per day removed is proportionally adjusted to the full design capacity, a rate of 939.2 pounds per day of pollutants are removed per 1988 equivalent million dollars spent.

In addition, major noticeable water quality improvements in the Blackstone River have occurred as a result of the upgrading. Large organic and nutrient reductions have caused significant instream dissolved oxygen concentration improvements. Water quality standards for dissolved oxygen are often met in areas that were once close to zero mg/l.

FIGURE 26

BLACKSTONE RIVER

BOD AND SS LOADING COMPARISONS

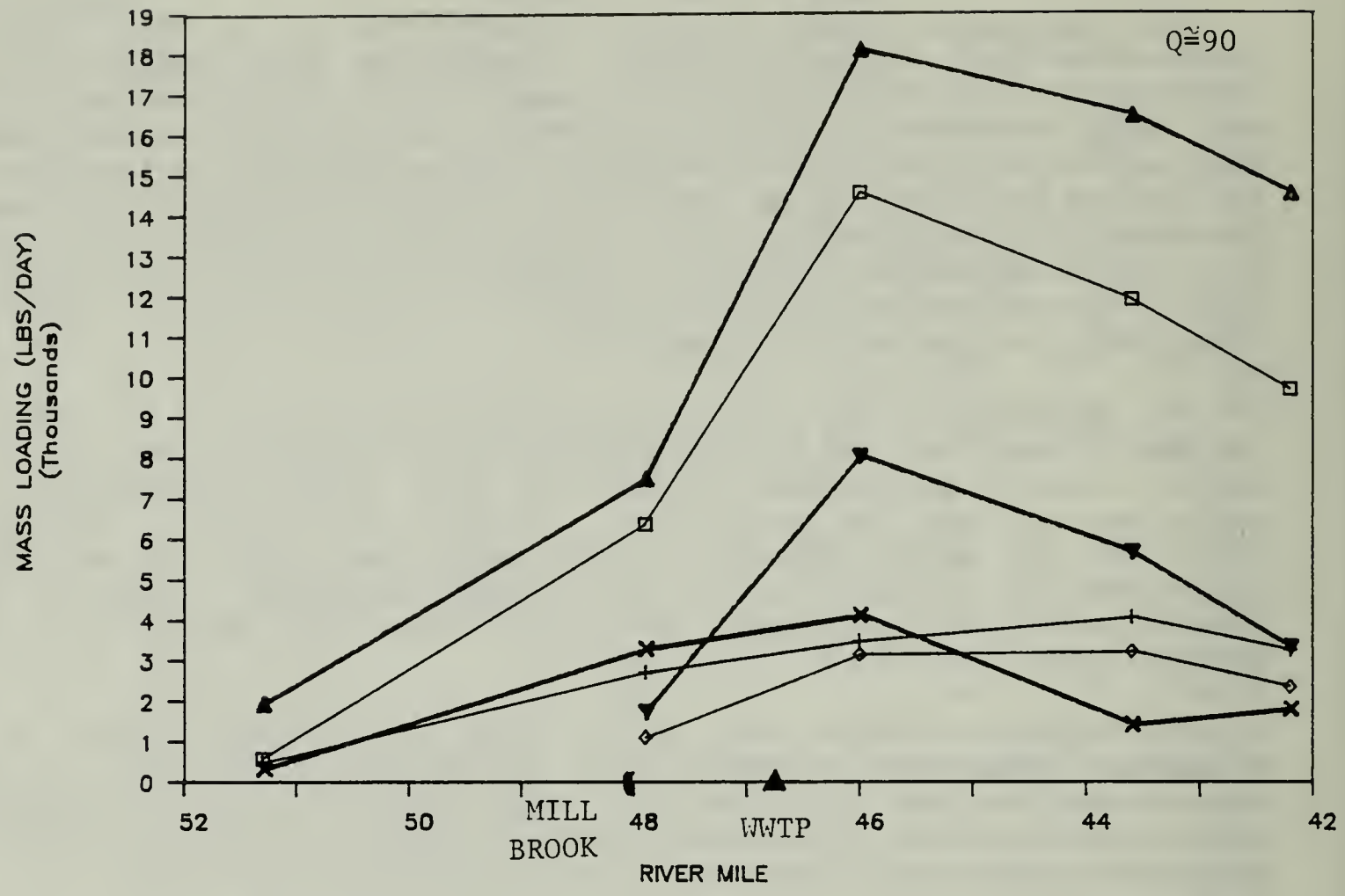


FIGURE 27

BLACKSTONE RIVER

NH3 AND TP LOADING COMPARISONS

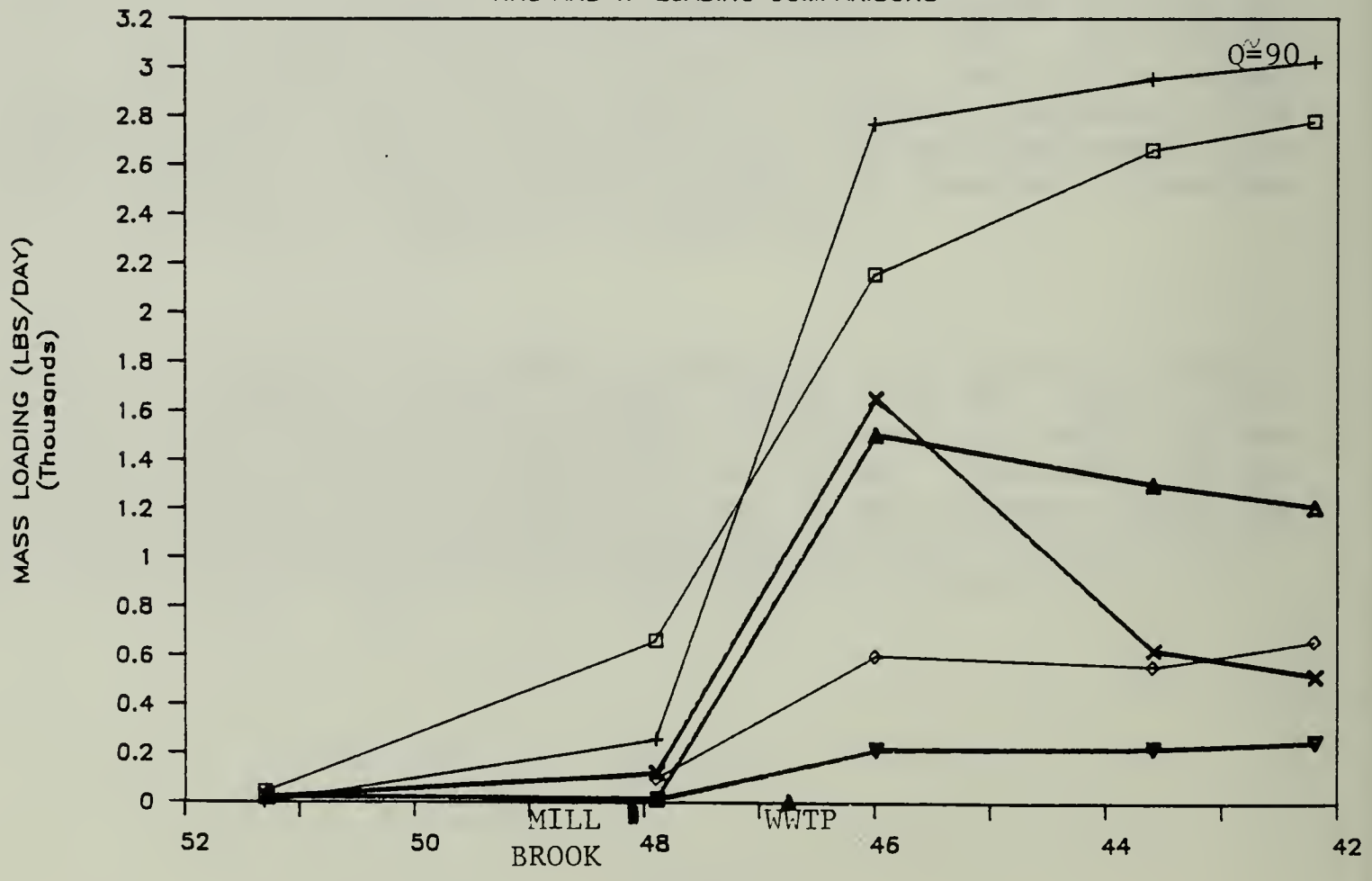
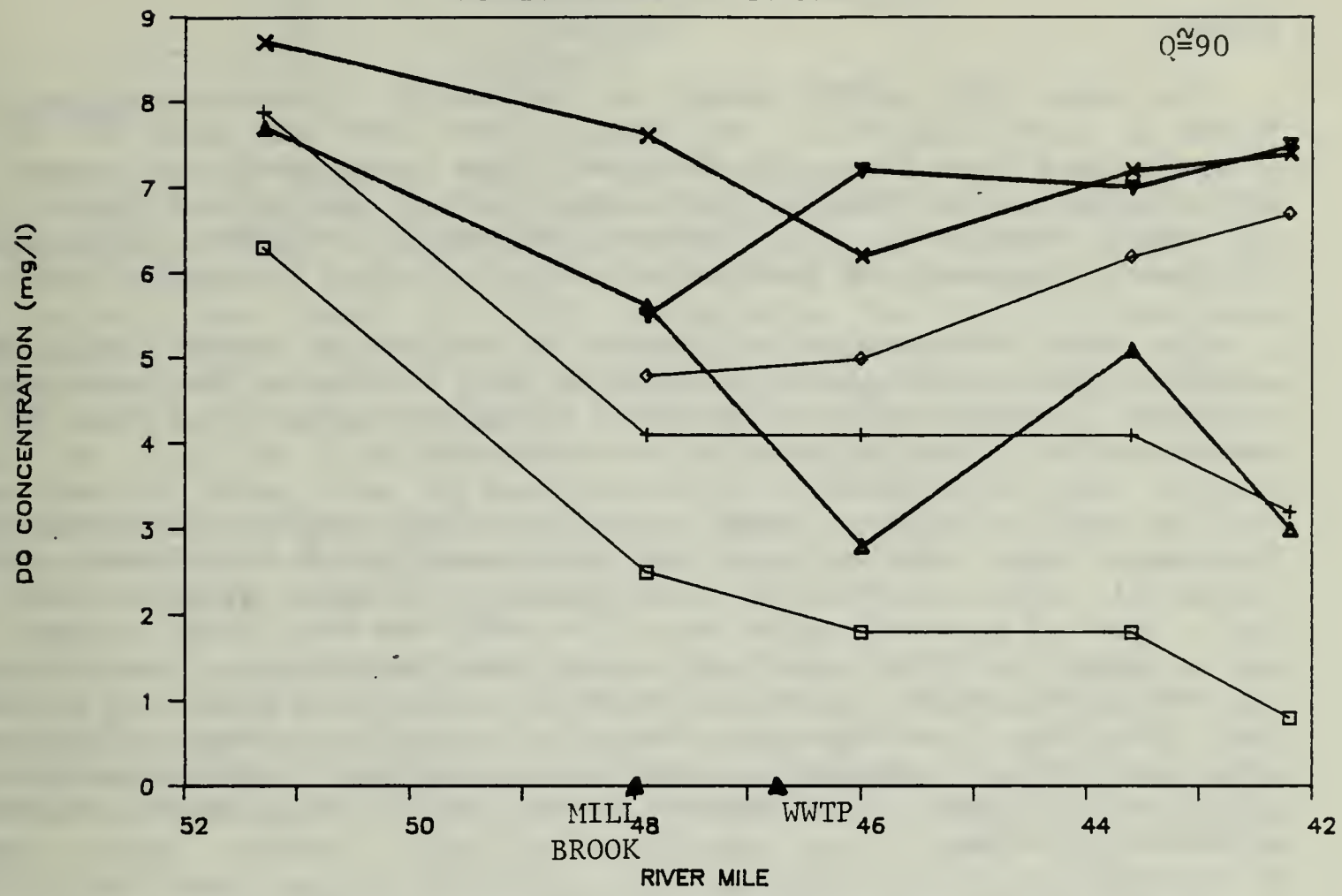


FIGURE 28

BLACKSTONE RIVER

INSTREAM MIN AND MAX DO COMPARISONS



WARE WWTP

History

The Ware WWTP (NPDES Permit No. MA0100899) discharges to the Ware River at river mile 9.5. The original Ware WWTP was built in 1964 in response to a plan for a 2.4 MGD plant to be constructed in 3 stages with a hydraulic load of 800,000 gpd for each stage. The first stage was a 0.8 MGD plant treating a mixed industrial-domestic wastewater with primary treatment. The plant had discharge limits of 125 mg/l for both BOD and SS.

The Ware WWTP received 40,000 gpd of industrial wastes from a paper company. (The remaining 510,000 gallons were domestic.) The paper company occasionally discharged colors using metallic powders which colored the wastewater and affected bacteria in the digester.

The WWTP's discharge caused excessively high phosphorus concentrations instream. The nutrient enriched waters exhibited significant diurnal dissolved oxygen fluctuations and minimum DO's often dropped below 3.0 mg/l. One and one-half miles below the WWTP the Ware River becomes slow and sluggish as it flows through farms and pasturelands. Solids settle out and nitrification occurs in the stream. Six miles below the discharge the Thorndike dam impounds the river causing further settling and decomposition of partially treated sewage and textile wastes from discharges in Ware. High sediment oxygen demand and nutrients caused an abundance of algae.

Due to the river loadings and WWTP upsets, DWPC ordered construction of a secondary WWTP to begin by February 1970 and be completed by February 1971. It was decided that the upgraded facility would also handle the town's industrial wastewater. This addition prompted pilot studies by the towns consulting engineers to study the effects of the industrial wastewater on the normal removal process and on the phosphorus removal system. The studies caused the planning and construction to be delayed.

In 1979 construction of a new upgraded and expanded wastewater plant began. The plant was upgraded from a 0.8 MGD primary plant to a 2 MGD advanced secondary treatment plant with nitrification and phosphorus removal. The new plant went into operation in February 1985 and has year-round limits of 25 mg/l for BOD and SS and seasonal limits of 1.0 mg/l for NH3 and TP. In addition, several industries in Ware that had previously discharged to the Ware River were tied into the WWTP with pretreatment.

The Ware River at the WWTP has a 7-day, 10-year low flow of 19.86 cfs. The expanded WWTP's design flow is 2 MGD (3.1 cfs), providing the effluent with a 6.4:1 dilution.

WWTP Loading

Since the upgrading in 1985 the WWTP has been sampled only five times: three times during water quality surveys conducted in 1985 after the plant went into operation, and twice in October 1988. The plant had ammonia limit violations in two of the five samples and phosphorus violations in every effluent sample after the upgrading (See Appendix A). The Ware WWTP still provides considerable pollutant reductions as listed below:

BOD - 94 % Reduction
SS - 97 % Reduction
NH3 - 93.5 % Reduction
TP - 53 % Reduction

River Loading

Three one day synoptic surveys were conducted on the Ware River in April, July and August 1985. No other surveys have been conducted since the upgrading. Other surveys were conducted in 1972 and 1980 before the WWTP was upgraded. Since two different sets of before and after surveys had similar flows, dates, and water temperatures, two sets of comparisons were made; 7/15/80 vs. 7/15/85 and 8/29/72 vs. 8/21/85. A USGS gage is located at river mile 8.8, just below the discharge. The similar flows were 77 cfs in 7/80 vs. 79 cfs in 7/85 and 76 cfs in 8/72 vs. 84 cfs in 8/85. The remaining flows for each station were estimated. Mass loadings were based on these flows and each parameters concentration. Mass loadings were calculated for one station above the WWTP (river mile 11.7; the WWTP is at river mile 9.5) and three stations below the WWTP (river miles 8.8, 8.3, and 4.4) (See Appendix B and Figures 29-34).

The mass loadings instream between the 1980 and 1985 surveys were noticeably reduced only at the first station below the discharge. The remaining stations had similar loadings between 1980 and 1985. The most noticeable pollutant decreases and instream dissolved oxygen increases were between the 1972 and 1985 surveys. During the thirteen years between these surveys, several industrial discharges were either tied into the WWTP or had some sort of treatment installed prior to their discharge to the Ware River. These eliminations probably played an important role in water quality improvements. During both survey comparisons the flows were very high. The effluent was receiving a dilution of approximately 78:1.

Cost/Benefit

The cost to plan, design and construct the upgraded Ware WWTP and build an extension of the Ware River interceptor sewer was $3,284,000. The cost was funded by a 90 % state-only grant. A revised Federal PL92-500 eliminated federal funds for treatment plants being upgraded with industrial discharge tie-ins. Industries were to pay a higher percentage of the cost to cover the federal share. Plants under construction prior to the change, however, continued to receive their federal funds. To equalize the industries shares the state paid the federal portion of the municipalities affected. The state funds contributed $2,889,000 (88 %) and the local community paid for the remaining $395,000 (12 %). The 1980 funds are equivalent to a 1988 total of $4,581,000.

The 2 MGD plant was constructed at a cost of $1.64 dollars/gallon, or $2.29 dollars/gallon 1988 equivalent. The upgraded plant removed an average of 1,945 pounds/day of BOD, SS, NH3 and TP at a rate of 592.3 lbs/day per million (424.6 lbs/day 1988 million) Appendix C. The plant is operating at 29% of design capacity. When adjusted to full capacity, a rate of 1464.1 lbs/day of pollutants are removed per 1988 million dollars.

The plant reduced the instream pollutant loadings and increased the instream dissolved oxygen. The plant has also allowed for the addition of pretreated industrial wastes, eliminating discharges to the Ware River.

FIGURE 29

WARE RIVER

BOD AND SS COMPARISONS 1980 VS. 1985

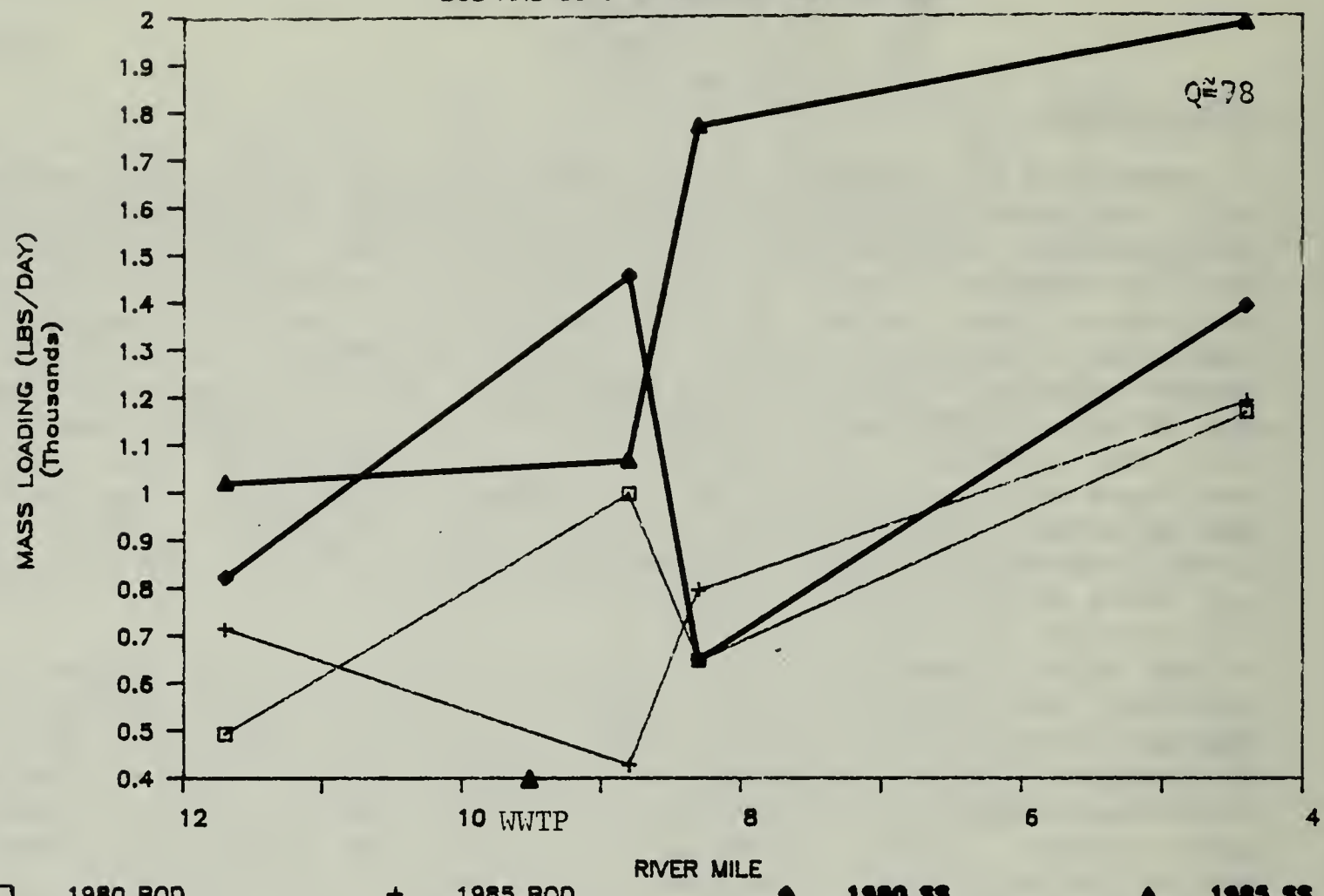


FIGURE 30

WARE RIVER

NH3 AND TP COMPARISONS 1980 VS. 1985

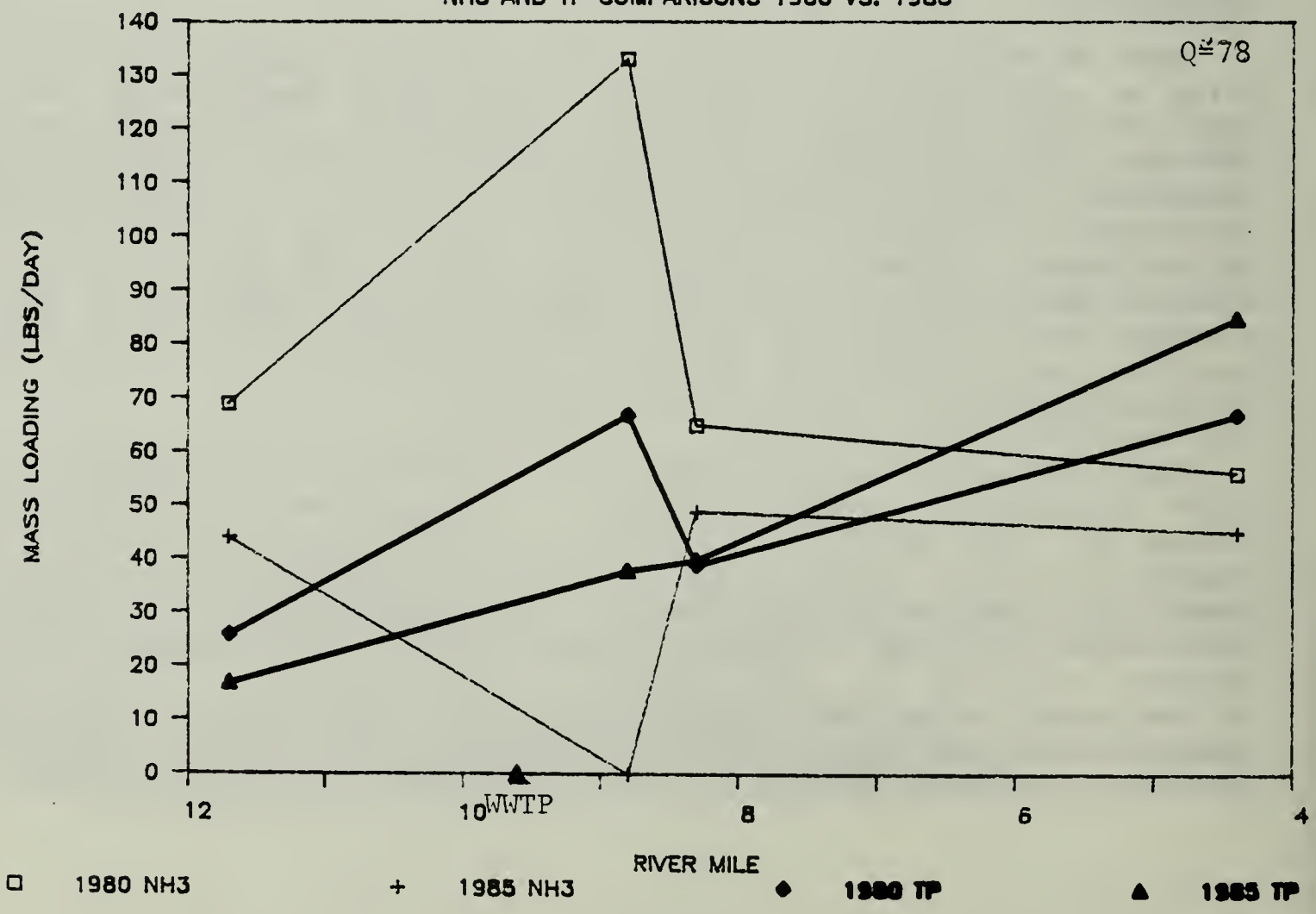


FIGURE 31

WARE RIVER

AVERAGE DO COMPARISON 1980 VS 1985

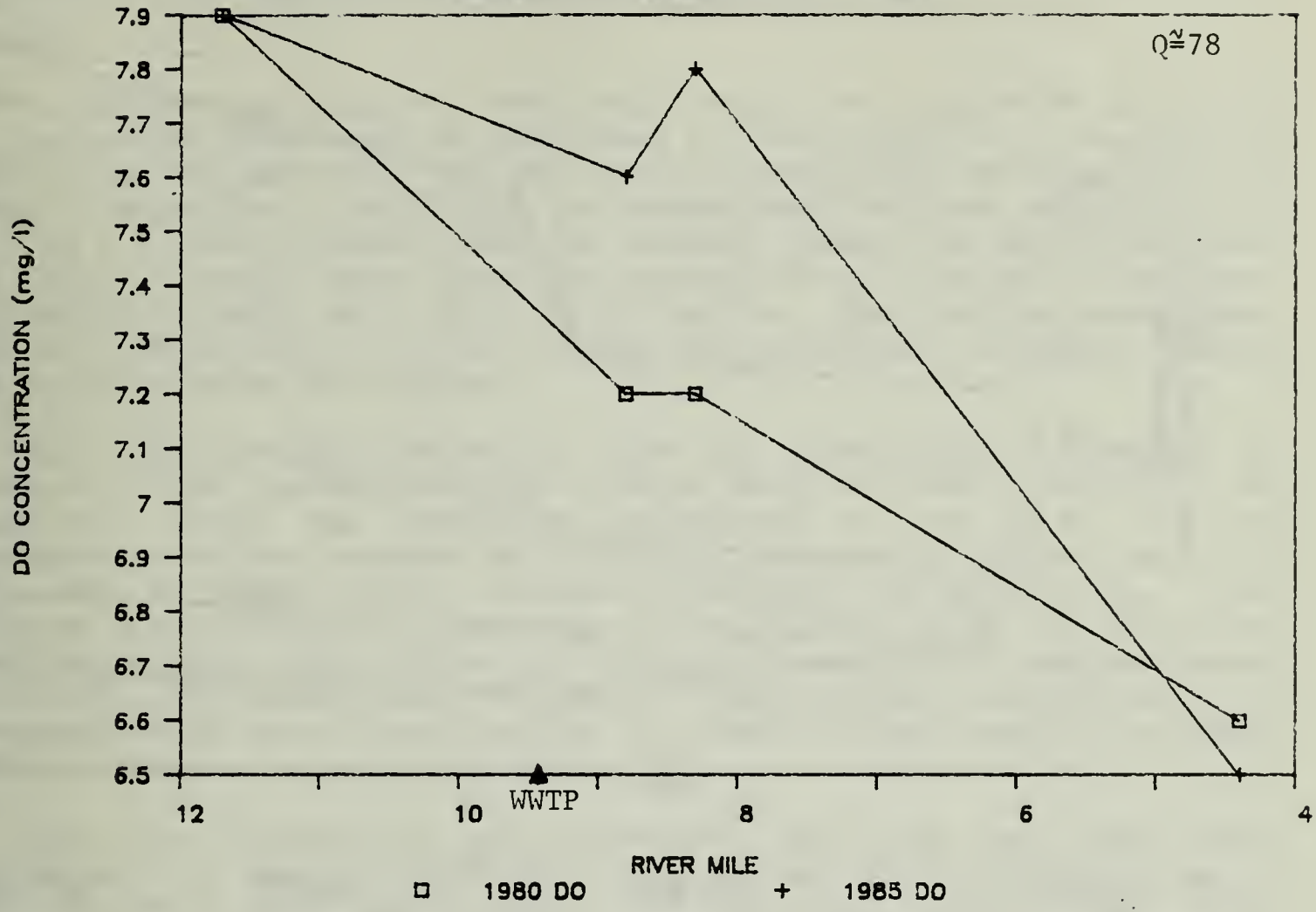


FIGURE 32

WARE RIVER

AVERAGE DO COMPARISON 1972 VS. 1985

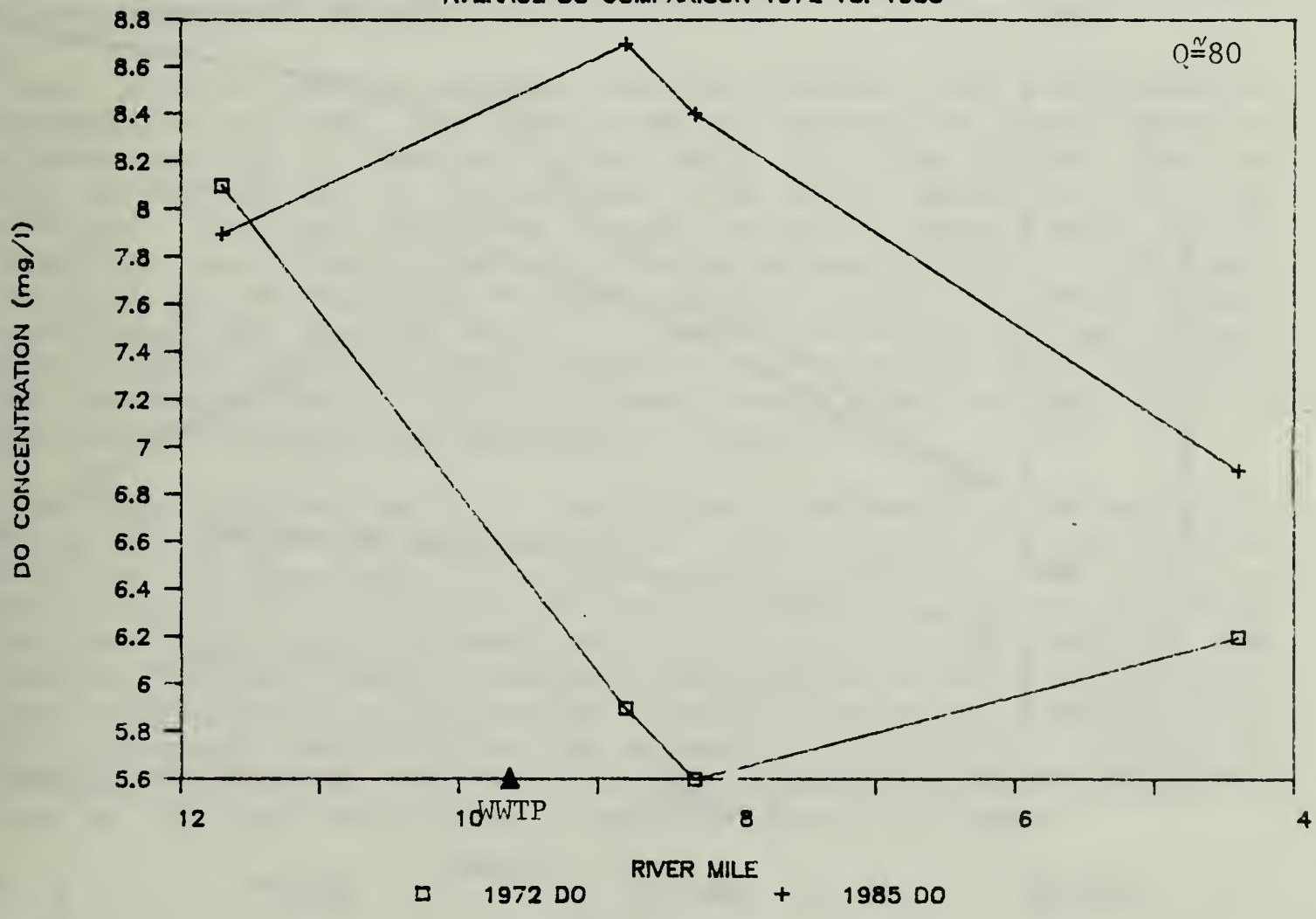


FIGURE 33

WARE RIVER

BOD AND SS COMPARISONS 1972 VS. 1985

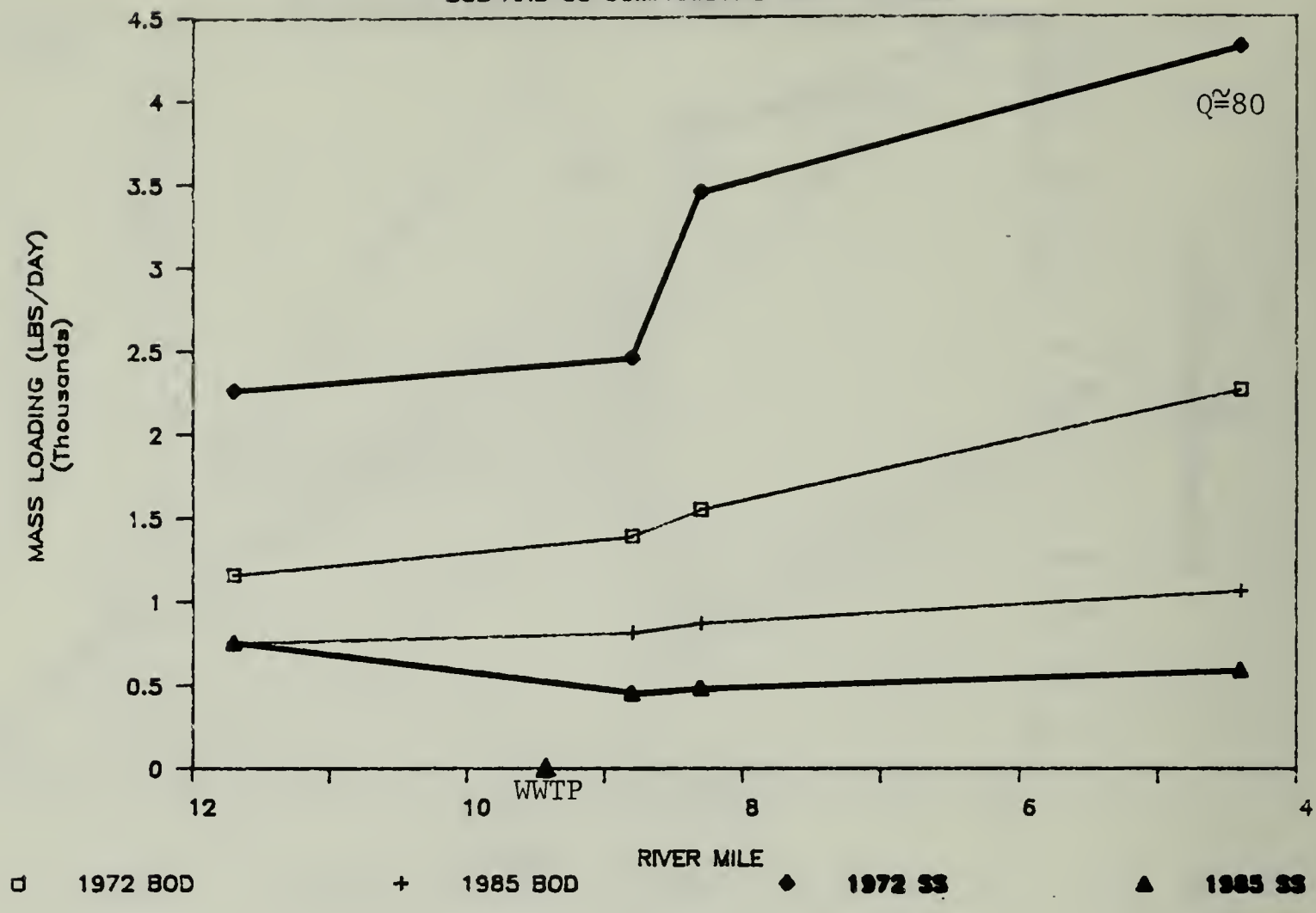
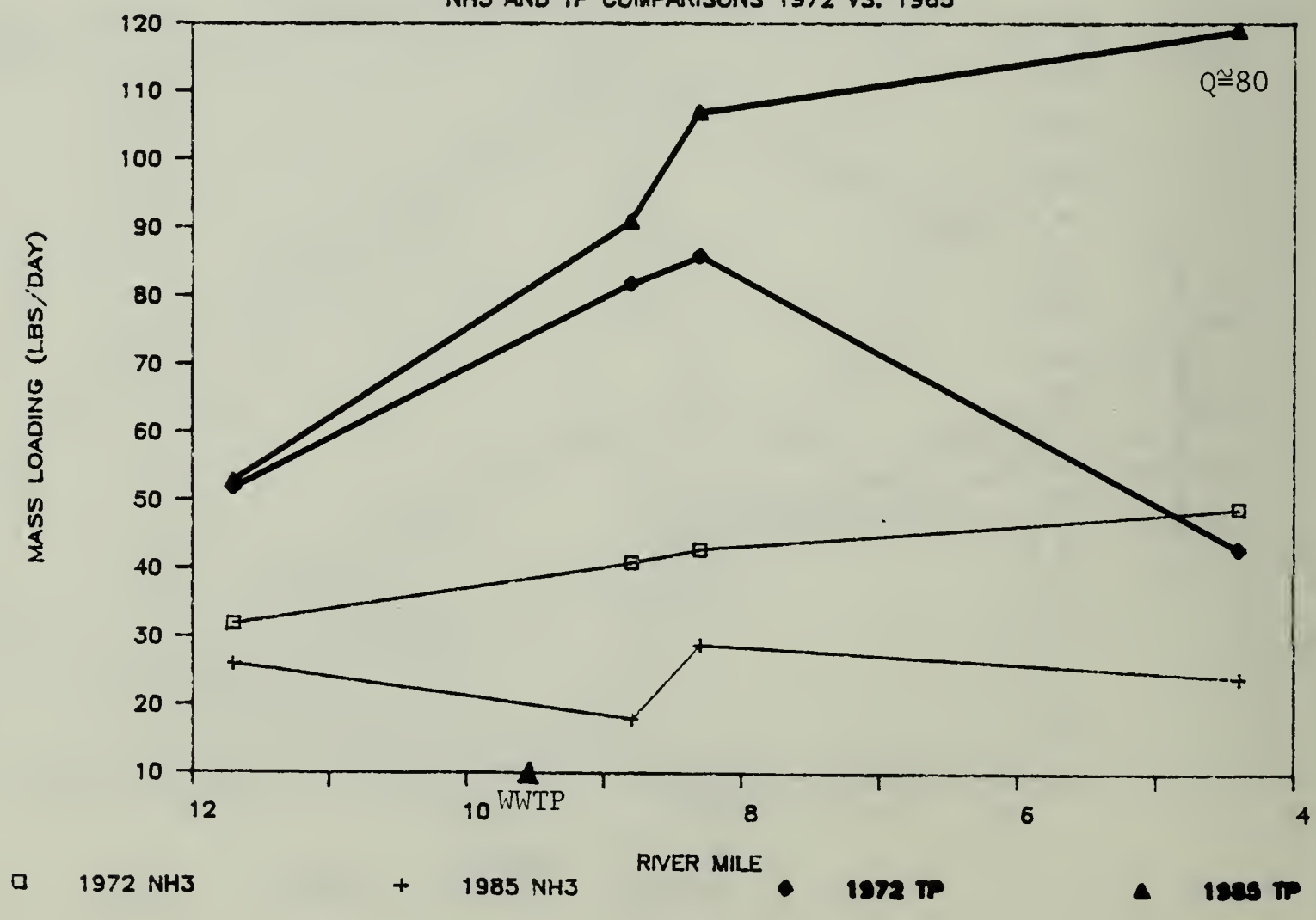


FIGURE 34

WARE RIVER

NH3 AND TP COMPARISONS 1972 VS. 1985



WESTBOROUGH REGIONAL WWTP

History

The Westborough Regional WWTP (NPDES Permit No. MA0100412) discharges to the Assabet River near the headwaters at river mile 30.2. The regional WWTP treats the wastewater for the towns of Westborough and Shrewsbury and parts of Hopkinton. Originally the Westborough WWTP was constructed in 1971 as a 1.1 MGD extended aeration secondary plant with sand filter beds for final polishing (which were used between May and October). The plant had secondary limits of 30 mg/l for BOD and SS. The plant was overloaded, with an average flow of 1.2 to 1.5 MGD and even higher during wet weather due to infiltration and inflow.

Less than a mile downstream from the Westborough discharge, the Shrewsbury WWTP discharged to the Assabet River at river mile 29.4. The Shrewsbury plant was originally constructed in 1963 as a 1.75 MGD secondary plant with aerated grit chambers, comminutor, primary settling, high rate trickling filter, secondary settling and chlorination. The effluent flowed through a long pipe to the Assabet River for discharge. Like Westborough, high inflow and infiltration during wet weather caused overloads and operational problems. The effluent quality from the Shrewsbury WWTP was of poor quality, and often did not meet its secondary effluent limits of 30 mg/l for BOD and SS.

Both the Westborough and Shrewsbury wastewater treatment plants discharged to a slow and sluggish section of the river with 7Q10 flows of 3.51 cfs and 5 cfs, respectively. The discharges received very little dilution from the stream. With both treatment plants needing upgrading and expansion, and both frequently overloaded during wet weather causing operational problems, the water quality of the Assabet River was degraded. The close proximity of the two discharges augmented the instream water quality problems even further.

Poor effluent quality caused elevated ammonia, BOD and phosphorus concentrations instream. The ammonia and BOD exerted an oxygen demand on the water causing a dissolved oxygen sag, with the minimum dissolved oxygen occurring at an impoundment four miles downstream from the discharges. The high nutrients caused excessive algae blooms in the impoundments, which caused further dissolved oxygen violations. The years of settling and accumulation of insufficiently treated solids and organic matter through the sluggish sections of the river and in the impoundments further resulted in large oxygen demands to the overlying water. Dissolved oxygen concentrations at the impoundment were close to zero, causing objectionable odors and many complaints by the public.

In 1985, construction of a new regional wastewater treatment plant began at the Westborough plant to treat the wastewater from the towns of Westborough and Shrewsbury. The new Westborough Regional WWTP went into operation during the late spring of 1987. In June 1987, the old Shrewsbury plant was tied into the regional plant and the old discharge was eliminated. The new advanced secondary facility is a 7.68 MGD plant with primary clarification, multi-channel oxidation, secondary clarification, sand filtration, post-aeration and seasonal chlorination. Sludge is processed by composting. The new plant has seasonal limits of 15 mg/l for BOD and SS, 1.5 mg/l for NH3 and 6.0 mg/l for dissolved oxygen.

The upgraded plant has caused significant decreases in instream BOD and ammonia which have resulted in remarkable increases in dissolved oxygen in the Assabet River.

WWTP Loading

Numerous water quality and wastewater surveys have been conducted on the Assabet River and Westborough and Shrewsbury WWTP's. Ten days of before effluent data were collected during the same days at both the Westborough and Shrewsbury plants. Data were collected during the same days and the two sets of mass loading values were added to determine a single before loading value. Ten days of effluent data from the regional WWTP were tabulated for mass loading calculations as after data to be compared to the combined before data. (See Table A-20 to A-22, Appendix A). The following pollutant reductions were observed due to the upgrading at the Westborough Regional WWTP, and elimination of the Shrewsbury plant:

BOD - 84 % Reduction
SS - 96 % Reduction
NH3 - 96 % Reduction

There was a 13 % decrease in phosphorus loading despite the plant not being required to have phosphorus removal.

River Loading

During the period 1985 to 1986, before the new plant went on line and again for the period 1986-1987 after the WWTP went on line, monthly one-day synoptic water quality surveys of the Assabet River were conducted. There was only one set of surveys that had similar flows. The summer of 1985 was fairly wet with higher flows and the summer of 1987 was warm and dry with lower flows. The two similar flows occurred during the surveys conducted on July 17, 1985 and September 1, 1987. The water temperatures were slightly different so percent saturation is also examined when comparing dissolved oxygen.

Flow measurements were taken at a USGS gage in Maynard, located at river mile 7.7. Using drainage areas and flow factors, the flows for the remaining stations were estimated. Mass loadings were calculated based on these flow measurements and the instream concentrations.

Five water quality sampling stations were compared. Before the treatment plants were upgraded and combined, the lowest dissolved oxygen in the dissolved oxygen sag occurred at river mile 26.5 at an impoundment in Northborough. The fifth station illustrated the dissolved oxygen increase following the sag. One station above the Westborough plant (river mile 31.0) and four stations below both plants (river miles 29.2, 28.3, 26.5, and 24.2) were compared.

The instream pollutant loadings, in particular BOD and ammonia exhibited decreased greatly. There was a corresponding large increase in instream dissolved oxygen, bringing the concentration from an average value of less than 1 mg/l (5% Saturation) to an average concentration of 6.5 mg/l (71% Saturation). This latter concentration is well above the water quality standard of 5.0 mg/l. Loading comparisons are tabulated in

Appendix B, and plotted in Figures 35-37. Instream ammonia concentrations decreased more than 96 %, BOD loads decreased more than 80 %, and SS loads decreased approximately 65 % .

Cost/Benefit

The total cost to plan, design and construct the regional Westborough WWTP was $30,298,000. This was funded by a federal grant of $22,419,000 (74 %), a state grant of $3,828,000 (12.6 %) and local funds of $4.050,000 (13.4 %). The 1985 funds total $32,631,000 in 1988 dollars.

The cost to construct the upgraded 7.68 MGD plant was $2.10 dollars per gallon or $4.25 dollars per gallon 1988 equivalent. The upgraded plant removes an average of 3,390 pounds per day of BOD, SS and NH3. The cost to remove these loadings is 112.0 lbs/day per million dollars spent or 103.9 lbs/day removed per 1988 million dollars (See Appendix C). The plant is currently operating at 42% of its design capacity. When the pounds per day removed is proportionally adjusted to the full capacity, a rate of 247.3 pounds per day of pollutants are removed per 1988 equivalent million dollars spent.

The upgrading of the Westborough plant to include the flows from Shrewsbury eliminated the Shrewsbury WWTP discharge to the Assabet River. The upgraded plant also provided much better treatment so dramatic water quality improvements have been noted. Large decreases in BOD and NH3 loads resulted, which increased the instream dissolved oxygen from concentrations below 1.0 mg/l to concentrations meeting water quality standards (above 5.0 mg/l).

FIGURE 35

ASSABET RIVER

BOD AND SS LOADING COMPARISONS

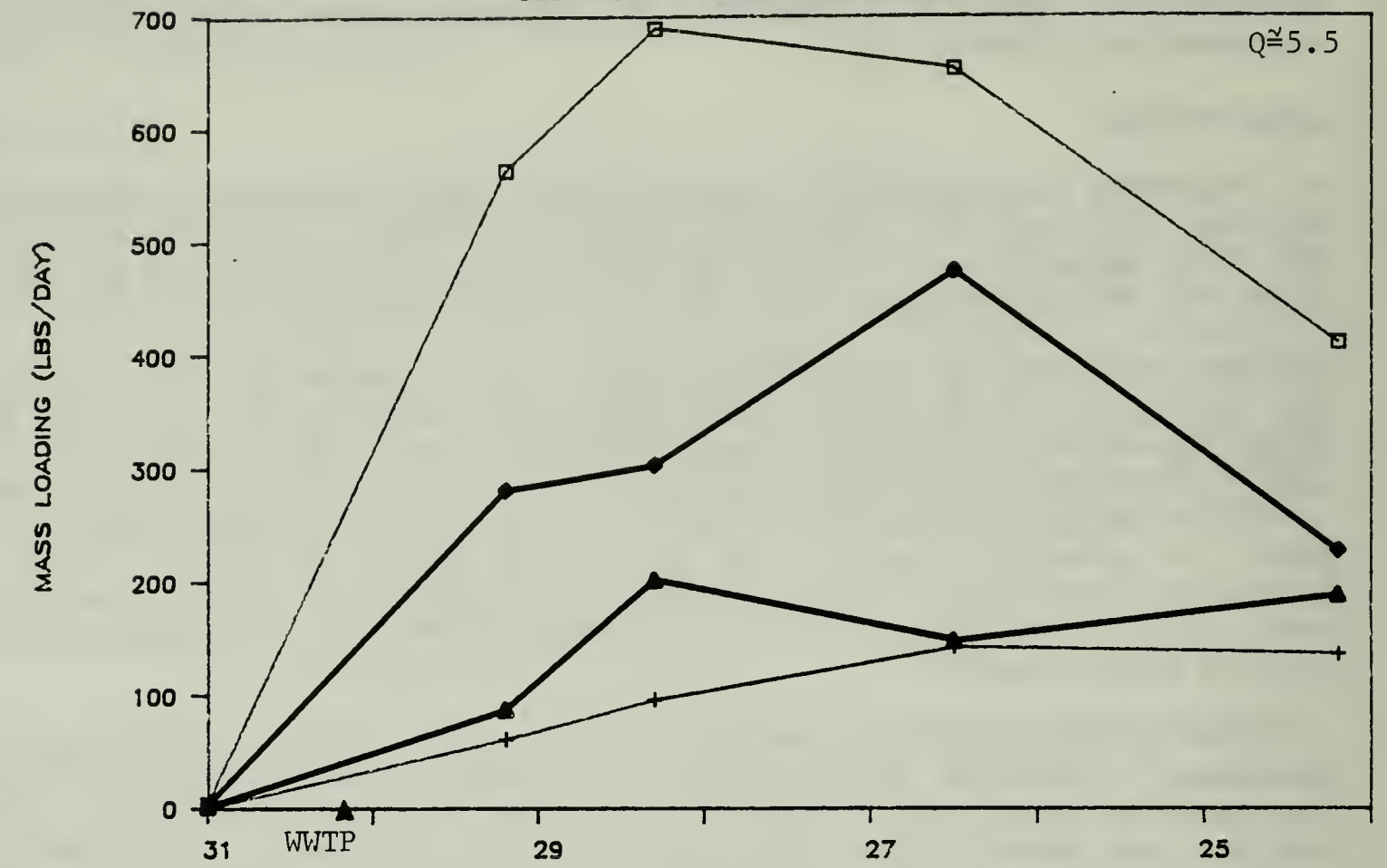


FIGURE 36

ASSABET RIVER

NH3 LOADING COMPARISON

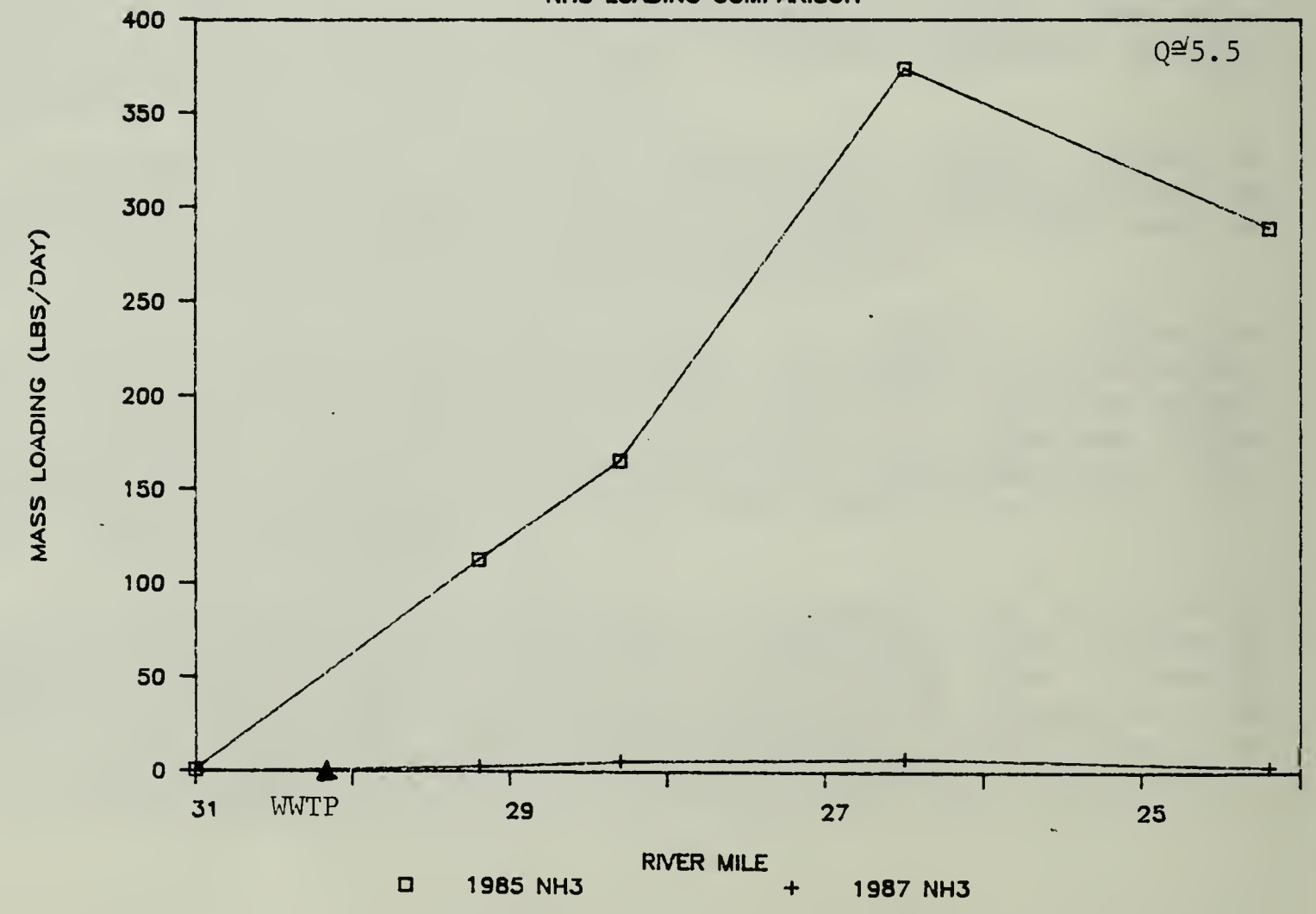


FIGURE 37

ASSABET RIVER

AVERAGE DO COMPARISONS

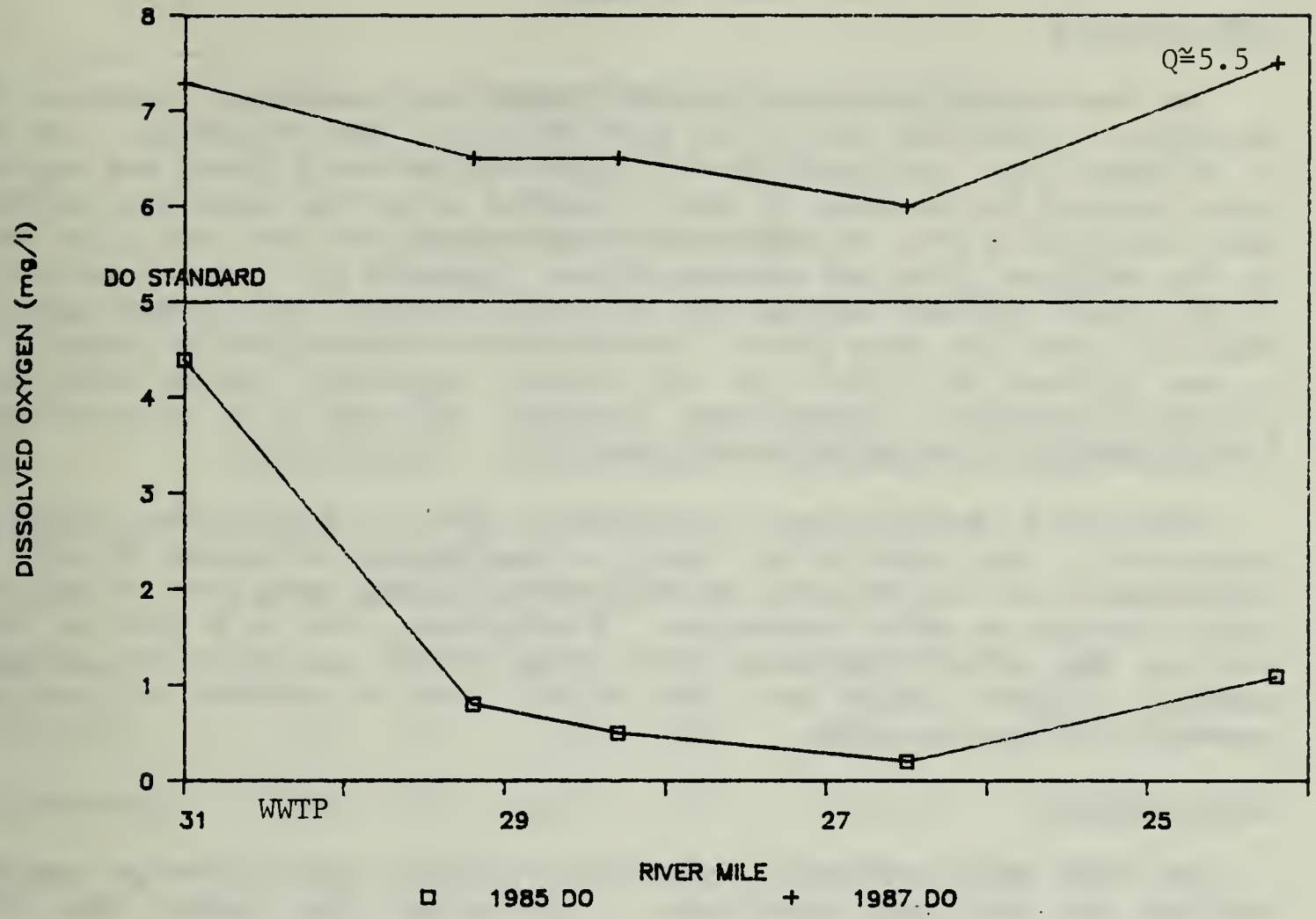
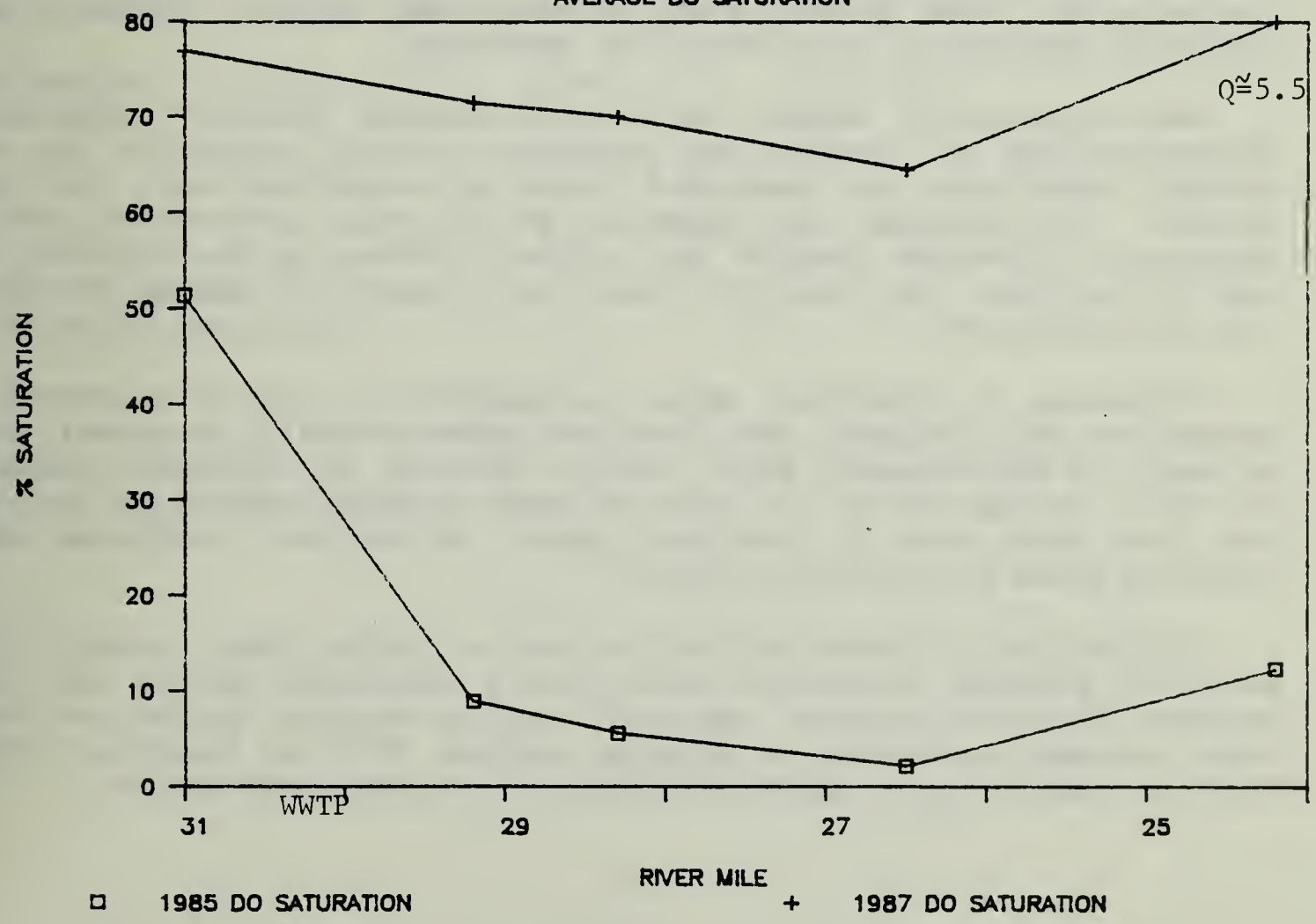


FIGURE 38

ASSABET RIVER

AVERAGE DO SATURATION



DISCUSSION

WWTP Loadings

Ten Wastewater Treatment Plants (WWTP) that have been upgraded from secondary to advanced within the past ten years were evaluated. Ten days of effluent data collected by the DEQE-DWPC before a plant was upgraded were compared to ten days of data collected after the plant was upgraded. Mass loadings of BOD, SS, NH3 and TP were calculated for each plant based on the effluent flow and concentrations (Appendix A). Percent reductions in pollutant loadings between the effluents "before" and "after" upgrading data were made for each plant. Reductions are summarized in Tables 2 and 3, and plotted in Figure 39. In general, upgrading caused significant pollutant reductions in effluent loadings, with 85 % or more pollutant load reductions observed at most plants.

Errors in analysis may be present due to insufficient data for comparison. Ten days is not always a representative amount of data for comparison. At some WWTP's, the DEQE-DWPC did not even have ten days for either before or after scenarios. Furthermore, due to a lack of data, some of the after days were from dates before or after the stricter seasonal effluent limits went into effect, when no ammonia or phosphorus removal would be occurring.

River Loadings

For each WWTP analyzed, the river receiving the discharge was also analyzed for pollutant reductions. One survey from before the WWTP's upgrading was compared to one survey after the WWTP's upgrading. Surveys were compared if the instream flow and antecedent weather conditions were similar. Mass loading calculations were made based on the instream flow and instream pollutant concentrations. Data from one station above the discharge and three to four stations downstream from the discharge were tabulated (Appendix B) and plotted for comparison.

WWTP upgradings caused noticeable instream pollutant reductions. Concentrations of ammonia and phosphorus usually exhibited the most obvious reductions, and suspended solid concentrations were the least obvious. On occasion, the suspended solids would increase or have no observable difference despite the reduced loading in the effluent. The lack of instream load reduction could be a result of outside influences and upstream inputs.

Increases in dissolved oxygen accompanied the large decreases in ammonia and BOD loadings. The dissolved oxygen generally increased enough to meet the Massachusetts Water Quality Standard for dissolved oxygen of 5.0 mg/l. There were a few instances when standards were still violated, but they were due to upstream inputs, or wetland conditions which naturally cause low dissolved oxygen.

Difficulties in these analyses are due to limited data, variable flows and other instream influences. Water quality comparisons during high flows produces different results from water quality compared during low flows. Other instream inputs such as nonpoint sources, CSO's or industrial inputs may vary from survey to survey altering the instream water quality.

TABLE 2

SUMMARY OF AVERAGE WWTP POLLUTANT LOADINGS

BEFORE AND AFTER UPGRADING

(All results in lbs/day)

WWTP	BOD		SS		NH3		TP	
	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER
Attleboro	1,540	210	809	204	541	30	201	101
Brockton	5,024	680	10,226	173	2,032	682	584	197
Leominster	1,461	473	1,741	750	570	386	208	40
Mansfield	332	24	467	15	83	1.0	49	3.7
Middleborough	1,116	46	2,193	77	114	3.3	*	
Milford	662	105	450	67	365	18	109	7.8
N. Attleborough	976	131	1,189	97	180	56	78	29
UBWPAD	15,560	993	19,624	1,491	1,997	145	*	
Ware	945	58	970	30	109	7.1	30	14
Westborough	1,315	217	2,163	92	231	9.7	*	

* No phosphorus removal

FIGURE 39

LOAD REDUCTIONS

BOD, SS & NH3 BEFORE UPGRADING

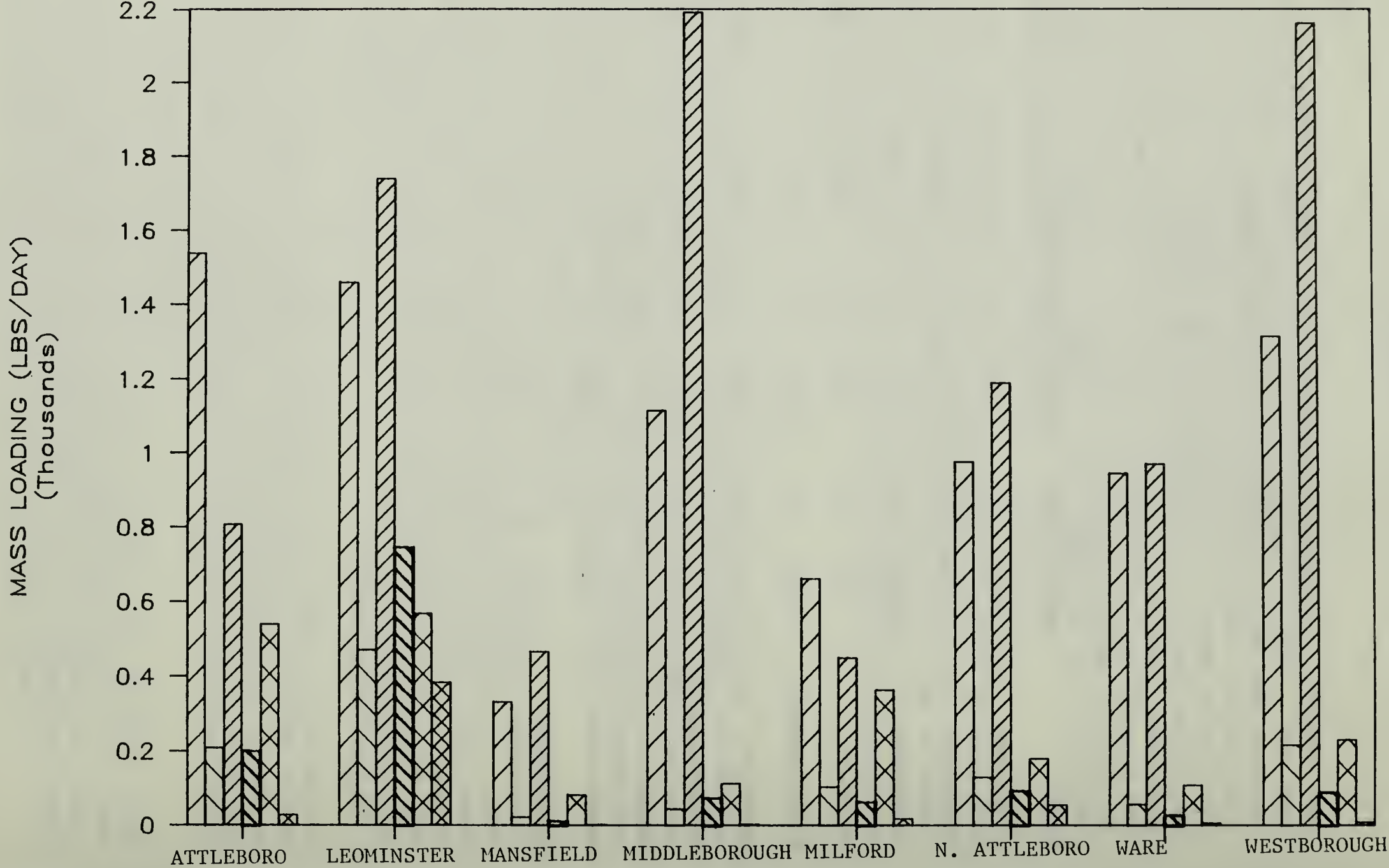


TABLE 3

SUMMARY OF
% LOADING REDUCTIONS

WWTP	BOD	SS	NH3	TP
Attleboro	86	75	94.5	50
Brockton	86.5	98	66	66
Leominster	68	57	32	81
Mansfield	93	97	99	92
Middleborough	96	96	97	*
Milford	84	85	95	93
N. Attleborough	86.5	92	69	62.5
UBWPAD	94	92	93	*
Ware	94	97	93.5	53
Westborough	84	96	96	*

* No phosphorus removal

Cost/Benefit Analysis

The cost to plan, design and construct each upgraded advanced WWTP was obtained at the DEQE Construction Grants office in Boston and is summarized in Table 4. Each plant was constructed and funded during different periods throughout the past ten years. The total cost for each plant was thus adjusted to an equivalent 1988 dollar amount using the ENR Construction Cost Index History table. Both original and 1988 dollars were compared, but better correlations were obtained when comparing 1988 dollars.

Cost/gallon calculations for each plant were made using cost in millions divided by the design gallons of the plant in MGD. These are summarized in Table 5. The average cost/gallon (1988 dollars) to upgrade a secondary plant to advanced treatment (based on the ten WWTP's studied) was $5.00 per gallon (s = 3.16) with a correlation coefficient relating construction cost to WWTP gallons of r = 0.54. The average cost/gallon to upgrade a WWTP based on the dollar value when construction first began (the original cost), was $3.38 (s = 2.54) and the correlation coefficient was r = 0.24. This is more random and scattered than the 1988 dollar comparison. From the data it appears the larger the total capacity of the plant the lower the cost/gallon to construct. Large plants are more economical to construct.

Several factors may affect the average cost/gallon value and correlation coefficient. First of all, the Mansfield plant was included in this average even though an entirely new plant was constructed and no parts of the former plant were used. In addition, several of the plants' total costs also included the construction and installation of interceptor sewers, force mains and pumping stations in addition to the treatment works upgrading costs. These additional costs could not be separated from the total cost but would probably also aid in the improving of the receiving rivers water quality.

Furthermore, some plants increased their capacity by twofold or more during the upgrading and construction while other plants had little to no increase in capacity added during construction. Adding extra capacity can also increase the price.

The next cost/benefit comparison was between the total pounds/day removed vs. million dollars spent, or amount of pollutant loadings removed from the wastewater effluent compared to the amount of total money spent for the entire upgrading. Pounds per day removed were calculated by subtracting the average pounds per day of BOD, SS, NH3 and TP observed after the upgrading from the average pounds per day observed before the upgrading.

The difference in loadings for each parameter and the total loadings difference was divided by the total cost (in millions). Both the original ($ M) cost during construction and the cost based on 1988 ($ M-1988) dollars was divided into the lbs/day removed. Each individual wastewater treatment plants loading/cost calculations are presented in Appendix C.

The summary of all WWTP's is presented in Table 6. From the calculations based on the ten WWTP's studied, the average lbs/day/$M was 315.5 with a standard deviation s = 365.8. The correlation coefficient between lbs/day removed and $M was r = 0.32. These high standard deviations indicate the variability is too great to have any meaning.

The average lbs/day removed per $M-1988 was 184.0 with a standard deviation s = 176.1. The correlation coefficient between lbs/day removed and $M-1988 was r = 0.59. Thus, equalizing the cost of construction to similar dollar values reduced the amount of scatter. There is still a low correlation and no definite trend was noticed.

None of the wastewater treatment plants are operating at design capacity. Thus the pounds per day of pollutants removed per million dollars compared the removals at the operating capacity versus the total construction dollars at the design capacity. To equalize total cost to total capacity, the pollutant removal rates were adjusted up (by flow proportioned ratios) to an equivalent removal rate for the plant at design capacity. The average adjusted pounds per day removed (design capacity) per total cost (1988 dollars) is 416.0 with a standard deviation of 478. The standard deviation is again higher than the average, indicating a large variation. Thus there does not appear to be any correlation between the amount of money spent to upgrade a plant and how many total pounds per day of BOD, SS, NH3 and TP are removed. When relating total pounds per day of pollutants removed to the size of the plant in MGD, there was a correlation. The calculated correlation coefficient (r) was equal to 0.96.

A breakdown of each individual parameters pound per day removal per total cost (adjusted and not adjusted, is listed in Table 7). From the ten plants studied, of the total pounds per day of pollutants removed, an average of 39.9% is from BOD removal, 47.7% is SS removal, 9.8% is ammonia removal and 4% is total phosphorus removal.

The pounds per day removed for each individual pollutant are also listed in Table 8. Average removal loads for the ten plants and the corresponding standard deviation were also calculated. Standard deviations were often higher than the average value indicating removal rates vary from plant to plant and cannot be predicted.

One place for an error in this cost analytical approach could be that three of the ten WWTP's did not have phosphorus removal. The lack of phosphorus lbs/day removed reduced the loading reductions observed at those plants.

Costs were not compared to instream pollutant reductions due to the numerous outside influences. The water quality conditions of the river upstream (and downstream) of the effluents discharge can vary, and influence the impact of the WWTP's effluent on the river. Instream flow can be low or high, providing little or a lot of dilution for the effluent. Furthermore, upstream discharges of CSO's could cause such poor instream water quality conditions that the effluent would cause very

little further degradation. Instream conditions also vary depending on the nature of the stream. Sluggish wetlands or impounded rivers with high organic settled matter and algae cause more problems than rapidly flowing streams with riffles and rocks. Thus, comparing ten instream pollutant reductions, each from one set of surveys with different flows and stream characteristics to other receiving streams with different flows and stream characteristics for cost comparison does not provide reliable pollutant/ cost reductions for comparative analysis.

No comparisons were made between the amount of money spent and the number of river miles now meeting standards as a result of the money. Some rivers' water quality was dramatically improved, but due to upstream discharges of poor quality or wetland conditions, previous dissolved oxygen violations continued. Often times there were additional benefits to upgrading a WWTP besides improving the dissolved oxygen above 5.0 mg/l that cannot be measured and compared with costs. These include reducing instream solids and settling in impoundments, decreased nutrient concentrations and resulting eutrophication, and increased wastewater capacity at the plants.

TABLE 4

SUMMARY OF WWTP UPGRADE FUNDING

WWTP	FEDERAL GRANT ($)	STATE GRANT ($)	LOCAL SHARE ($)	TOTAL COST ($)	TOTAL COST 1988 DOLLAR
Attleboro	23,073,000	4,659,000	4,404,000	32,136,000	52,253,000
Brockton	39,124,000	5,798,000	4,410,000	49,332,000	68,818,000
Leominster	18,215,000	3,636,000	4,029,000	25,880,000	36,103,000
Mansfield	23,574,000	4,601,000	3,087,000	31,262,000	39,953,000
Middleborough	4,399,000	880,000	664 000	5,943,000	12,136,000
Milford	14,262,000	2,852,000	2,087,000	19,201,000	21,371,000
N Attleborough	12,436,000	2,487,000	2,156,000	17,079,000	27,770,000
UBWPAD	17,446,000	3,778,500	2,439,500	23,664,000	52,529,000
Ware	---	2,889,000	395,000	3,284,000	4,581,000
Westborough	22,419,000	3,828,000	4,050,000	30,297,000	32,631,000
Total $	174,948,000	35,408,500	27,721,500	238,078,000	348,145,000

TABLE 5

COST/GALLON SUMMARY

WWTP	ORIGINAL TOTAL COST	1988 TOTAL COST	MGD	COST/ GALLON	COST/ GAL-1988
Attleboro	32,136,000	52,253,000	8.6	$3.74	$6.08
Brockton	49,332,000	68,818,000	18	$2.74	$3.82
Leominster	25,880,000	36,103,000	9.3	$2.78	$3.88
Mansfield	31,262,000	39,953,000	3.13	$9.83	$12.77
Middleborough	5,943,000	12,136,000	2.5	$2.38	$5.10
Milford	19,201,000	21,371,000	4.3	$4.47	$4.78
N. Attleborough	17,079,000	27,770,000	4.6	$3.71	$6.04
UBWPAD	23,664,000	52,529,000	56	$0.42	$0.94
Ware	3,284,000	4,581,000	2.0	$1.64	$2.29
Westborough	30,297,000	32,631,000	7.68	$2.10	$4.25
Average	$ 23,808,000	$ 34,815,000	11.6	$3.38	$5.00

TABLE 6

SUMMARY OF LBS/DAY/$M

WWTP	ORIGINAL TOTAL COST	1988 TOTAL COST	AVG.LB/ DAY REM	LBS/DAY/ $ M	LBS/DAY/ $ M-1988
Attleboro	33,136,000	52,253,000	2,546	79.2	48.7
Brockton	49,332,000	68,818,000	16,003	324.4	232.5
Leominster	25,880,000	36,103,000	2,331	90.1	64.6
Mansfield	31,262,000	39,953,000	887	28.4	22.2
Middleborough	5,943,000	12,136,000	3,297	554.8	271.7
Milford	19,201,000	21,371,000	1,388	72.3	64.9
N. Attleborough	17,079,000	27,770,000	2,110	123.5	76.0
UBWPAD	23,664,000	52,529,000	27,876	1178.0	530.7
Ware	3,284,000	4,581,000	1,945	592.3	424.6
Westborough	30,297,000	32,631,000	3,390	111.9	103.9
Average	$ 23,808,000	$ 34,815,000	6,177	315.5	184.0

TABLE 7

POUNDS/DAY REMOVAL PER 1988 MILLION DOLLARS SPENT
(Current and adjusted capacities)

WWTP	BOD	ADJ BOD	SS	ADJ SS	NH3	ADJ NH3	TP	ADJ TP
Attleboro	25.5	38.1	11.6	17.3	9.8	14.6	1.9	2.9
Brockton	63.1	91.7	146.1	212.3	19.6	28.5	3.7	5.4
Leominster	27.4	49.3	27.4	49.4	5.1	9.2	4.7	8.4
Mansfield	7.7	22.3	11.3	32.7	2.1	5.9	1.1	3.3
Milddleborough	88.2	238.9	174.4	472.5	9.1	24.8	**	**
Milford	26.1	35.5	17.9	24.3	16.2	22.0	4.7	6.4
N.Attleborough	30.4	37.5	39.3	48.4	4.5	5.5	1.8	2.2
UBWPAD	277.3	490.8	218.1	386.0	35.3	62.4	**	**
Ware	193.6	667.7	205.2	707.6	22.3	76.8	3.5	12.
Westborough	33.6	80.1	63.5	151.1	6.8	16.1	**	**
Total	772.9	1751.7	914.8	2101.6	130.8	265.8	21.4	40.6
Average	77.3	175.2	91.5	210.2	13.1	26.6	3.1	5.8

** No Phosphorus Removal

TABLE 8

CHANGE IN LBS/DAY AND PERCENTAGE OF LOAD REDUCTION

WWTP	BOD DIFF	BOD (%)	SS DIFF	SS (%)	NH3 DIFF	NH3 (%)	TP DIFF	TP (%)
Attleboro	1330	(52.2%)	605	(23.8%)	511	(20.1%)	100	(3.9%)
Brockton	4344	(27.1%)	10053	(62.8%)	1350	(8.4%)	256	(1.6%)
Leominster	988	(42.4%)	991	(42.5%)	184	(7.9%)	168	(7.2%)
Mansfield	308	(34.7%)	452	(51.0%)	82	(9.2%)	45	(5.1%)
Middleborough	1070	(32.5%)	2116	(64.2%)	111	(3.4%)	**	
Milford	557	(40.1%)	383	(27.6%)	347	(25.0%)	101	(7.3%)
N. Attleborough	845	(40.0%)	1092	(51.8%)	124	(5.9%)	49	(2.3%)
UBWPAD	14567	(52.3%)	11457	(41.1%)	1852	(6.6%)	**	
Ware	887	(45.6%)	940	(48.3%)	102	(5.2%)	16	(0.8%)
Westborough	1098	(32.4%)	2071	(61.1%)	221	(6.5%)	**	
Average	2599	(39.9%)	3016	(47.4%)	488	(9.8%)	105	(4.0%)
Std. Dev. (s)	4353	(8.4%)	4135	(14.0%)	612	(7.0%)	83	(2.6%)

** No Phosphorus Removal

CONCLUSIONS

Large pollutant reductions occur in wastewater effluents and in receiving streams when wastewater treatment plants are upgraded to advanced treatment with nitrification (and possibly phosphorus removal). Ten wastewater treatment plants that were upgraded to advanced treatment with nitrification were studied. Seven of the plants also had phosphorus removal. Pollutant mass loadings observed between the "before" and the "after" upgrading decreased greatly with an average load reduction of 85 % or greater. These pollutant load reductions caused corresponding pollutant load reductions in the receiving river for several miles below the WWTP's discharge. High organic load reductions caused subsequent increases in the instream dissolved oxygen concentrations. Unless other discharges were present or the river flowed through wetlands or eutrophic impoundments, the upgrading of the WWTP (with nitrification) resulted in the elevation of the dissolved oxygen to concentrations that met water quality standards.

The treatment plants were built at an average 1988 cost of $5.00 dollars per gallon. The plant's upgradings reduced the plant's pollutant load by an average of 6,177 pounds per day of BOD, SS, NH3, and TP removed per day with a total pollutant rate of 184 pounds per day removed per 1988 million dollars spent to upgrade.

These numbers relate the actual pollutant removal to the total cost. None of the wastewater treatment plants are at full capacity. When pollutant pounds per day removed at partial capacity are adjusted to full capacity operations, the average pollutant removal rate increases to an average of 415.7 pounds per day of pollutants removed per 1988 equivalent million dollars spent. This is broken down to an average of 175.2 pounds per day of BOD removed per 1988 equivalent million dollars spent, 210.2 pounds per day of suspended solids removed, 26.6 pounds per day of NH3 removed and 5.8 pounds per day of TP removed per 1988 equivalent million dollars spent. All costs are based on the total cost to plan, design and construct the upgraded plant and are not based on the individual cost to construct each parameters separate removal. (i.e. chemical feed and settling for phosphorus, etc.) Removal for BOD, SS, and NH3 are often all the same equipment and processes.

These expenditures have improved the water quality of the receiving waters tremendously. The removal of organic pollutants has improved instream dissolved oxygen concentrations to water quality standards and concentrations capable of sustaining fish and other aquatic life instream. The removal of solids eliminate the excess solids instream that settle and fill in impoundments and sluggish stream sections. Less settling lowers the sediment oxygen demands and helps eliminate instream dissolved oxygen demands. Nitrification and phosphorus removals eliminate the high instream nutrient concentrations which lead to excessive plant and algae growth and eutrophication. All these removals lead to beneficial results for fish habitats and human uses (swimming, boating, etc.).

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APPENDIX A

TABLE A-1

ATTLEBORO WWTP BEFORE UPGRADING

DATE	FLOW cfs	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day
3/24-25/76	7.12	84	3230	16	615	-	-	4.3	165
10/13-14/76	5.49	51	1512	13	385	14	415	4.2	125
9/26-27/77	6.01	93	3018	30	974	-	-	6.5	211
11/13-14/78	6.2	39	1306	54	1808	19	636	9.5	318
11/14-15/78	6.05	37	1209	44	1437	17	555	8.5	278
11/15-16/78	5.89	28	890	44	1399	19	604	8.1	258
6/15-16/81	3.88	39	817	16	335	19	398	8.6	180
6/16-17/81	3.88	66	1382	24	503	24	503	9.1	19
6/17-18/81	3.88	66	1383	19	398	22	461	8.5	178
8/25-26/81	6.67	18	648	6.5	234	21	756	2.9	104
AVG.	5.51	52	1540	27	809	19	541	7.0	201

- Not Sampled

TABLE A-2

ATTLEBORO WWTP AFTER UPGRADING

DATE	FLOW cfs	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day
7/9-10/84	8.8	1.5	71	6.0	285	0.3	14	2.9	138
7/23-24/84	9.33	-	-	3.5	176	0.04	2.0	2.8	141
7/24-25/84	9.14	3.6	178	5.0	247	0.02	1.0	2.4	118
7/25-26/84	9.09	4.2	206	4.0	196	0.12	5.9	2.1	103
8/20-21/84	8.80	3.6	171	3.0	143	0.05	2.4	1.6	76
8/21-22/84	8.64	6.2	289	6.0	280	0.33	15	1.9	89
8/22-23/84	8.82	4.5	214	4.0	191	0.31	15	2.2	105
9/17-18/84	8.96	3.6	174	1.5	73	1.6	77	1.5	73
9/18-19/84	8.74	8.0	378	6.0	283	2.2	104	1.8	85
9/19-20/84	8.70	4.4	207	3.5	164	1.3	61	1.8	85
AVG.	8.90	4.4	210	4.2	204	0.63	30	2.1	101

NOTE:

- not analyzed

TABLE A-3

BROCKTON WWTP BEFORE UPGRADING

DATE	FLOW cfs	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day
5/19-20/80	20.38	16	1,761	14	1,541	11	1,211	4.4	484
12/6-7/82	14.73	3.6	286	11	875	19	1,511	2.0	159
12/7-8/82	16.59	19	1,702	26	2,329	21	1,881	4.1	367
12/8-9/82	15.04	19	1,543	25	2,030	21	1,706	4.6	374
1/17-18/83	39.53	40	8,538	1483	1,592	18	3,842	5.0	1,067
5/2-3/83	37.05	43	8,603	77	15,405	12	2,401	3.8	760
5/3-4/83	36.43	70	13,771	177	34,820	15	2,951	5.8	1,141
5/4-5/83	36.74	31	6,150	34	6,745	13	2,579	3.5	694
6/16/83	21.70	58	6,796	56	6,562	11	1,289	4.5	527
7/19/83	13.49	15	1,093	5.0	364	13	947	3.7	270
AVG.	25.17	31	5,024	57	10,226	15	2,032	4.1	584

TABLE A-4

BROCKTON WWTP AFTER UPGRADING

DATE	FLOW cfs	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day
5/2-3/88	19.19	7.6	788	<1.0	<104	10	1,036	2.2	228
5/3-4/88	19.19	10	1,036	1.5	155	9.7	1,005	2.3	238
9/26-27/88	19.19	2.1	218	2.5	259	0.04	4.1	1.2	124
AVG.	19.19	6.6	680	1.5	173	6.5	682	1.9	197

TABLE A-5

LEOMINSTER WWTP BEFORE UPGRADING

DATE	FLOW cfs	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day
6/23-24/77	6.98	17	641	27	1,018	16	603	6.0	226
8/15-16/77	6.00	24	778	16	518	20	648	1.3	42
8/16-17/77	5.35	24	693	12	347	15	433	6.5	188
8/17-18/77	6.96	24	902	22	827	18	677	5.6	210
4/30-5/1/79	14.88	30	2,411	49	3,937	6.3	506	3.7	297
6/3-4/80	10.08	29	1,578	28	1,524	16	860	4.0	218
7/6-7/82	7.32	44	1,739	24	949	9.1	360	3.2	126
7/19-20/82	10.76	69	4,009	46	2,673	10	581	4.9	285
7/20-21/82	13.39	5.0	362	27	1,952	7.7	557	2.8	203
7/21-22/82	8.94	31	1,497	76	3,669	10	483	5.8	280
AVG.	9.07	31	1461	33	1741	13	570	3.8	208

TABLE A-6

LEOMINSTER WWTP AFTER UPGRADING

DATE	FLOW cfs	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day
3/25-26/85	9.3	18	904	24	1,205	12	603	0.58	29
5/6-7/85	7.75	14	586	19	795	13	544	1.0	42
6/3-4/85	8.37	7.2	325	3.0	136	0.22	9.9	0.45	20
9/3-4/85	7.44	11	442	22	884	11	442	1.4	56
9/4-5/85	7.13	2.8	108	19	732	8.6	331	1.4	54
AVG.	8.0	53	473	17	750	9.0	386	1.0	40

TABLE A-7

MANSFIELD WWTP BEFORE UPGRADING

DATE	FLOW cfs	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day
9/24-25/75	1.36	78	573	130	955	2.1	15	4.3	32
8/2-3/76	1.80	24	233	28	272	10	97	8.4	82
8/3-4/76	1.77	30	287	32	306	6.2	59	6.5	62
8/4-5/76	1.81	30	293	26	254	7.5	73	6.0	59
5/22-23/78	2.16	24	280	52	607	7.4	86	3.4	40
5/23-24/78	2.09	17	192	59	666	5.0	56	3.0	34
5/24-25/78	1.97	15	160	38	404	1.9	20	2.4	26
5/20-21/80	1.77	12	115	14	134	4.0	38	3.0	29
6/11-12/84	4.44	32	767	32	767	7.2	173	3.5	84
6/27-28/84	1.89	40	408	30	306	21	214	4.0	41
AVG.	2.11	30	332	44	467	7.2	83	4.4	49

TABLE A-8

MANSFIELD WWTP AFTER UPGRADING

DATE	FLOW cfs	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day
10/15-16/85	-	-	-	21	-	0.84	-	5.2*	-
10/16-17/85	-	7.8	-	11	-	0.65	-	5.3*	-
6/20-21/88	1.65	2.4	21	3.0	27	0.03	0.3	0.31	2.8
6/21-22/88	1.76	2.4	23	1.0	9.5	0.15	1.4	0.33	3.1
8/15-16/88	1.63	4.8	42	1.5	13	0.14	1.2	0.5	4.4
8/16-17/88	1.67	1.2	11	1.0	9.0	0.12	11	0.5	4.5
AVG.	1.68	2.7	24	1.6	15	0.11	1.0	0.41	3.7

* Phosphorus for premoval on seasonal basis, only.

TABLE A-9

MIDDLEBOROUGH WWTP BEFORE UPGRADING

DATE	FLOW cfs	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day
9/30-10/1/75	1.33	90	646	42	302	17	122	5.8	42
10/1-2/75	1.54	114	948	89	740	18	150	3.5	29
10/2-3/75	1.41	66	503	49	373	19	145	2.8	21
10/7/75	1.43	90	695	60	463	18	139	4.0	31
8/2-3/76	1.24	198	1,326	76	509	14	94	10	67
8/3-4/76	1.24	276	1,848	76	509	9.3	62	9.6	64
8/4-5/75	1.24	276	1,848	1,860	12,455	13	87	11	74
AVG.	1.35	159	1,116	65	483*	5	114	6.7	47

* does not include 8/4-5/75 data

TABLE A-10

MIDDLEBOROUGH WWTP AFTER UPGRADING

DATE	FLOW cfs	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day
7/22-23/80	0.93	6.6	33	16	80	1.1	5.5	6.4	32
9/2-4/80	1.07	2.4	14	4.0	23	0.9	5	5.0	29
7/22/81	1.01	4.8	26	6.0	33	0.06	0.3	1.3	7.1
7/23/81	0.87	3.0	14	5.0	23	0.12	0.6	1.2	5.6
9/8-9/81	1.07	0.9	5	0	0	0.10	0.6	5.0	29
9/9-10/81	1.01	1.5	8.2	1.0	5.5	0.10	0.5	5.0	27
6/20-21/88	2.29	12	148	22	272	1.1	14	5.2	64
6/21-22/88	2.29	9.6	119	15	185	0.27	3.3	3.0	37
8/15-16/88	1.94	6.9	72	5.0	52	0.18	1.9	7.0	73
8/16-17/88	1.86	2.0	20	10	100	0.17	1.7	4.9	49
AVG.	1.43	5.0	46	8.4	77	4.1	3.3	4.4	35

TABLE A-11

MILFORD WWTP BEFORE UPGRADING

DATE	FLOW cfs	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day
6/10-11/81	2.87	26	403	37	573	16	248	6.0	93
6/23-24/81	2.88	40	622	40	622	12	187	7.2	112
7/7-8/86	7.10	26	997	15	575	12	461	6.2	238
7/8-9/86	7.10	20	767	15	575	7.0	268	5.9	226
8/4-5/86	4.19	17	385	8.0	181	17	385	6.9	156
8/5-6/86	4.34	17	398	11	258	12	281	6.4	150
7/13-14/87	4.65	26	653	20	502	26	653	1.5	38
7/14-15/87	5.43	19	557	12	352	23	674	1.2	35
8/24-25/87	3.67	49	971	13	258	4.0	79	0.75	15
8/25-26/87	3.63	44	862	31	608	21	412	1.4	27
AVG.	4.59	28	662	20	450	15	365	4.3	109

TABLE A-12

MILFORD WWTP AFTER UPGRADING

DATE	FLOW cfs	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day
2/16-17/88	8.82	3.3	157	0.5	24	0.45	21	0.25	12
4/19-20/88	5.5	4.2	125	6.0	178	0.95	28	0.50	15
5/16-17/88	5.53	2.4	72	1.5	45	0.64	19	0.75	22
6/1-2/88	5.63	7.6	231	1.5	46	0.63	19	0.18	5.5
6/15-16/88	4.45	5.4	130	9.5	228	1.6	38	0.31	7.4
7/5-6/88	3.80	4.2	86	2.0	41	1.4	29	0.1	2.1
7/20-21/88	4.62	0.9	22	<1.0	<25	0.51	13	0.12	3.0
8/3-4/88	5.02	2.7	73	<1.0	<27	0.27	7.3	0.15	4.1
9/7-8/88	2.73	4.5	66	2.2	32	0.19	2.8	0.20	2.9
9/26-27/88	3.22	5.1	89	1.5	26	0.25	4.3	0.25	4.3
AVG.	4.93	4.0	105	2.6	67	0.69	18	0.28	7.8

TABLE A-13

NORTH ATTLEBOROUGH WWTP BEFORE UPGRADING

DATE	FLOW cfs	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day
5/8-9/73	4.5	33	802	190	4,617	7.6	185	3.6	87
5/9-10/73	4.5	42	1,021	32	778	7.0	170	3.3	80
5/10-11/73	4.5	46	1,118	34	826	7.2	175	3.8	92
2/23/76	4.50	45	1,094	27	656	-	-	-	-
10/12-13/76	3.41	57	1,050	22	405	-	-	4.4	81
9/26-27/77	4.81	54	1,403	30	779	-	-	3.2	83
11/15-16/78	1.86	34	341	26	261	19	191	4.2	42
AVG.	4.01	31	976	29	618*	10.2	180	3.8	77.5

- not analyzed

* does not include 5/8-9/73 data

TABLE A-14

NORTH ATTLEBOROUGH WWTP AFTER UPGRADING

DATE	FLOW cfs	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day
6/28-29/82	5.60	4.2	127	4.0	121	2.3	70	1.2	36
6/29-30/82	5.39	8.4	244	1.5	44	3.5	102	1.9	55
6/30-7/1/82	5.75	6.6	205	0.5	16	2.1	65	1.5	47
3/14-15/83	9.69	2.4	126	1.5	78	1.8	94	0.25	13
3/15-16/83	8.59	2.4	111	6.0	278	1.7	79	0.3	14
3/16-17/83	7.91	4.0	171	2.0	85	1.7	73	0.2	8.5
7/9-10/84	4.28	5.7	132	6.0	139	1.4	32	0.9	21
7/25-26/84	3.99	4.2	90	2.0	43	1.5	32	0.55	12
8/20-21/84	3.34	0.6	11	3.5	63	0.22	4.0	2.6	47
8/21-22/84	3.31	5.4	97	5.5	98	0.39	7.0	2.2	39
AVG.	5.79	4.4	131	3.3	96.5	1.7	56	1.2	29

TABLE A-15

WORCESTER STP BEFORE UPGRADING

DATE	FLOW cfs	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day
3/20-21/73	78.7	45	19,124	48	20,399	5.7	2,422	2.0	850
3/21-22/73	58.9	46	46,631	60	19,084	5.4	1,718	3.1	986
3/22-23/73	54.4	44	12,925	66	19,388	6.3	1,851	2.3	676
AVG.	64.0	45	15,560	58	19,624	5.8	1,997	2.5	837

TABLE A-16

UBWPAD AFTER UPGRADING, BEFORE NITRIFICATION

DATE	FLOW cfs	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day
3/19-20/85	53.48	6.0	1,733	15	4,331	11	3,176	3.1	895
4/16-17/85	51.46	11	3,057	23	6,391	11	3,057	4.5	1,250
4/17-18/85	51.15	8.4	2,320	44	12,153	9.1	2,514	2.5	691
4/21-22/85	45.57	-	-	17	4,183	11	2,707	1.4	345
4/22-23/85	53.94	2.4	699	21	6,117	11	3,204	2.1	612
6/17-18/85	46.5	35	8,789	14	3,515	9.2	2,310	3.0	753
6/19-20/85	35.5	11	2,109	13	2,492	11	2,109	3.0	575
6/18-19/85	37.2	13	2,611	21	4,218	10	2,009	3.0	575
7/15-16/86	60.45	-	-	3.5	1,143	0.25	82	3.5	1,143
7/22-23/86	40.77	14	3,082	17	3,743	13	2,862	4.5	991
AVG.	47.60	13	3,050	19	4,829	10	2,403	3.0	768

- not analyzed

TABLE A-17

UBWPAD AFTER NITRIFICATION

DATE	FLOW cfs	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day
6/13-14/88	50.69	5.1	1,396	6.5	1,779	0.51	140	1.2	328
6/14-15/88	49.91	6.3	1,698	5.0	1,348	0.83	224	1.0	270
8/1-2/88	47.43	3.6	256	5.0	1,281	0.47	120	2.4	615
8/2-3/88	48.05	2.4	623	6.0	1,557	0.37	96	2.6	675
AVG.	49.02	4.4	993	5.6	1,491	0.55	145	1.8	472

TABLE A-18

WARE WWTP BEFORE UPGRADING

DATE	FLOW cfs	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day
10/25-26/76	0.70	310	1172	230	869	19	72	6.4	24
10/26-27/76	0.70	230	869	150	567	28	106	8.6	33
9/14-15/77	0.90	219	1064	102	496	16	78	8.8	43
5/15-16/79	1.48	122	975	108	863	14	112	3.0	24
7/25-26/79	1.92	250	2592	330	3421	17	176	3.6	37
7/14-15/80	0.96	9	47	69	358	34	176	6.0	31
7/15-16/80	0.90	0.7	3.4	127	617	37	180	0.63	3.1
8/18-19/80	1.07	180	1040	128	740	17	98	7.5	43
8/19-20/80	1.03	99	551	140	779	0.17	0.9	4.0	22
8/13-14/81	1.06	198	1134	172	985	16	92	7.6	44
AVG.	1.07	162	945	156	970	20	109	5.6	30

TABLE A-19

WARE WWTP AFTER UPGRADING

DATE	FLOW cfs	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day
4/29-30/85	0.87	7.2	34	8.5	40	0.32	15	1.3	6.1
7/15-16/85	1.02	24	132	2.5	14	0.02	0.11	6.4	35
8/20-21/85	0.93	6.6	33	3.5	18	2.8	14	1.4	7.0
10/17-18/88	0.87	7.6	36	7.0	33	0.87	4.1	2.3	11
10/18-19/88	0.82	12	53	10	44	3.6	16	2.8	12
AVG.	0.90	11.5	58	6.3	30	1.6	7.1	2.8	14

TABLE A-20

WESTBOROUGH WWTP BEFORE UPGRADING

DATE	FLOW cfs	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day
8/6-7/79	1.55	11	92	6.5	54	2.4	20	5.4	45
8/7-8/79	1.49	6.0	48	14	113	0.2	1.6	4.0	32
2/24-25/81	2.45	47	622	348	4606	1.1	15	4.5	60
2/25-26/81	2.59	21	294	11	154	3.0	42	3.4	48
10/11-12/83	1.89	14	143	16	163	0.76	7.8	6.2	63
10/12-13/83	2.04	7.2	79	14	154	0.87	9.6	6.3	69
6/26-27/85	1.94	16	168	23	241	0.14	1.5	3.6	38
7/16-17/85	5.97	45	1451	119	3836	0.24	7.7	6.5	210
8/21-22/85	1.92	7.8	81	3.0	31	0.16	1.7	4.2	44
9/9-10/85	2.22	5.6	67	18	216	0.15	1.8	5.2	62
AVG.	2.41	18	305	57	957	0.9	11	5.0	67

TABLE A-21

SHREWSBURY WWTP BEFORE UPGRADING

DATE	FLOW cfs	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day
8/6-7/79	1.97	30	319	11	117	15	160	6.8	72
8/7-8/79	1.91	40	413	11	113	0.44	4.5	5.0	52
2/24-25/81	3.77	51	1,038	280	5,700	5.2	106	3.6	73
2/25-26/81	7.44	34	1,366	44	1,768	6.9	277	2.5	100
10/11-12/83	2.55	53	730	32	441	21	289	7.1	98
10/12-13/83	2.78	120	1,801	67	1,006	17	255	7.8	117
6/26-27/85	2.50	22	297	28	378	21	284	7.1	96
7/16-17/85	2.40	114	1,477	87	1,128	21	272	9.0	117
8/21-22/85	2.40	120	1,555	44	570	20	259	7.5	97
9/9-10/85	2.98	69	1,110	52	837	18	290	6.5	105
AVG.	3.07	65	1,011	66	1,206	15	220	6.3	93

APPENDIX B

TABLE B-1

ATTLEBORO WWTP

TEN MILE RIVER LOADING COMPARISONS

7/5/83

RIVER MILE** (STATION)	FLOW (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O. (mg/l) min	D.O. (mg/l) avg	D.O. (mg/l) max	(°F) Avg temp	Avg % sat
8.0(TM14)	52	7.5	2106	16	4493	0.4	112	0.56	157	6.1	6.9	7.8	72	78
7.0(TM15)	70**	4.5	1701	18	6804	0.95	359	0.68	257	5.8	6.6	7.7	72	75
5.8(TM16)	76	8.1	3324	24	9850	0.89	365	0.66	271	4.2	5.3	7.2	72	60
3.2(TM17)	83	6.0	2689	14	6275	0.46	206	0.74	332	5.0	7.2	9.8	72	82

7/24-25/84

RIVER MILE** (STATION	FLOW (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O. (mg/l) min	D.O. (mg/l) avg	D.O. (mg/l) max	(°F) Avg temp	Avg % sat
8.6(TM13)	40	2.7	583	4.0	864	0.05	11	0.34	73	6.4	7.3	8.5	75	85
7.0(TM14)	69*	2.7	1006	5.5	2049	0.10	37	0.38	142	5.6	7.2	8.1	73	83
5.8(TM15)	75	2.7	1094	6.5	2633	0.05	20	0.41	166	4.7	7.3	9.9	74	85
3.2(TM16)	82	1.5	664	5.5	2435	0.02	8.9	0.36	159	7.1	9.0	13.0	78	108

* Instream Flow Measurement
** Stations differ from year to year

TABLE B-2

BROCKTON WWTP

SALISBURY MATTFIELD RIVER LOADING COMPARISONS

7/19/83

RIVER MILE (STATION)	FLOW (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O. (mg/l) min	D.O. (mg/l) avg	D.O. (mg/l) max	(°F) Avg temp	Avg % sat
49.1(MS05)	4.0*	0.9	19	0.5	11	0.25	5.4	0.09	1.9	-	7.1	-	22	82
48.4(MS05A)	20	5.4	583	8.5	918	17	1836	3.6	389	-	6.5	-	23	76
47.1(MS06)	27.4*	12	1776	4.5	666	12	1776	3.9	577	-	3.1	-	24	36
45.6(MS064)	32	11	1901	3.5	605	13	2246	6.2	1071	-	1.5	-	24	18
44.5(MS07)	38	14	2873	3.5	718	14	2873	1.1	226	-	2.6	-	24	30

9/28/88

RIVER MILE (STATION)	FLOW (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O. (mg/l) min	D.O. (mg/l) avg	D.O. (mg/l) max	(°F) Avg temp	Avg % sat
49.1(MS05)	3.6*	4.5	87	4.0	78	0.13	2.5	0.06	1.2	6.2	6.4	6.5	17	65
48.4(MS05A)	23	8.4	1043	13	1615	0.30	37	0.88	109	7.3	7.3	7.3	19	78
47.1(MS06)	23.5	4.5	2919	8.0	994	0.28	35	0.70	87	6.5	7.0	7.5	19	74.5
45.6(MS06A)	24*	3.9	505	6.0	778	0.18	23	0.70	91	6.7	7.5	8.2	19	79
44.5(MS07)	24.5	3.3	437	5.0	662	0.20	26	0.57	75	7.0	7.6	8.2	18	80

* Instream Flow Measurements

TABLE B-3

LEOMINSTER WWTP

NORTH NASHUA RIVER LOADING COMPARISONS 8/79 - 9/85

8/27/79

RIVER MILE (STATION)	FLOW (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O. (mg/l) avg **	Avg temp (°F)	Avg % sat
47.8(NN10)	75	2.7	1094	3.5	1418	0.25	101	0.22	89	7.1	72	81
45.8(NN11)	86	3.0	1393	7.0	3251	1.7	789	0.7	325	7.5	72	85
43.8(NN12)	96*	5.1	2644	14	7258	0.82	425	0.67	347	6.9	70	77
39.8(NN13)	106	5.7	3263	17	9731	0.81	464	0.52	298	6.3	71	71

9/3/85

RIVER MILE (STATION)	FLOW (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O. (mg/l) avg **	Avg temp (°F)	Avg % sat
47.8(NN10)	69	3.3	1230	9.5	3540	0.16	60	0.11	41	8.6	64	90
45.8(NN11)	80	5.1	2203	9.5	4104	1.3	562	0.18	78	8.8	63	91
43.8(NN12)	90*	4.2	2041	15	7290	0.69	335	0.16	78	8.1	63	83
39.8(NN13)	100	3.9	2106	12	6480	0.61	329	0.20	108	8.0	63	82

* USGS Gage Flow Measurement
** No min or max DO data

TABLE B-4

LEOMINSTER WWTP

NORTH NASHUA RIVER LOADING COMPARISONS 7/79 - 6/85

7/31/79

RIVER MILE (STATION)	FLOW (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O.** (mg/l) avg	Avg temp (°F)	Avg % sat
47.8(NN10)	68	3.6	1322	8.0	2938	0.35	129	0.15	55	6.9	80	85
45.8(NN11)	76	5.7	2339	23	9439	1.4	575	0.54	222	6.8	79	83
43.8(NN12)	83*	4.8	2151	19	8516	0.83	372	0.42	188	6.4	79	78
39.8(NN13)	93	7.8	3917	18	9040	0.73	367	0.42	211	5.7	78	69

6/3/85

RIVER MILE (STATION)	FLOW (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O.** (mg/l) avg	Avg temp (°F)	Avg % sat
47.8(NN10)	65	3.9	1369	5.5	1931	0.36	126	0.21	74	7.5	68	82
45.8(NN11)	73	4.8	1892	6.0	2365	0.17	67	0.15	59	7.9	69	87
43.8(NN12)	80*	4.8	2074	9.0	3888	0.16	69	0.19	82	7.1	69	78
39.8(NN13)	90	5.1	2479	7.5	3645	0.08	39	0.18	87	7.5	70	83

* USGS Gage Flow Measurement
** No min or max DO data

TABLE B-5

MANSFIELD WWTP

BACK BAY BROOK WATER QUALITY DATA
Before and After Mansfield WWTP Removal

PARAMETER	DATE 6/27/84	8/19/87
Dissolved Oxygen (mg/l)	3.9	3.8
Temperature (°F)	70	72
% Saturation	43.4	43.1
BOD	3.6	-
SS	15	66
NH3	3.4	1.4
TP	1.4	0.53

* No flow measurements so mass loading is unknown.

TABLE B-6

MANSFIELD WWTP

THREEMILE RIVER LOADING COMPARISONS

8/5-7/75

RIVER MILE (STATION)	FLOW (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O. (mg/l) min	D.O. (mg/l) avg	D.O. (mg/l) max	(°F) Avg temp	Avg % sat
10.5(TH08)	9.4*	4.0	203	8.0	406	0.18	9.1	0.17	8.6	1.3	3.9	5.6	72	44
8.7(TH09)	12	2.1	136	4.0	259	0.23	15	0.17	11	0.5	3.7	5.7	72	42
6.6(TH11)	13	3.5	246	5.0	351	0.30	21	0.43	30	1.0	3.5	7.0	74	41
4.2(TH12)	15	2.6	211	3.8	308	0.14	11	0.28	23	2.5	4.1	5.7	73	47

8/16-17/88

RIVER MILE (STATION)	FLOW (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O. (mg/l) min	D.O. (mg/l) avg	D.O. (mg/l) max	(°F) Avg temp	Avg % sat
10.5(TH08)	9.9*	0.9	48	1.8	96	0.08	4.3	0.22	12	4.7	5.8	6.9	77	69
8.7(TH09)	12.5	0.8	54	2.8	189	0.02	1.4	0.12	8.1	4.2	5.4	6.5	77	65
6.6(TH11)	13.5	0.8	58	5.2	379	0.04	2.9	0.12	8.7	6.1	6.9	7.7	79	84
4.2(TH12)	16	0.9	78	3.0	259	0.06	5.2	0.10	8.6	4.8	5.6	6.4	76	66

* Instream Flow Measurement

TABLE B-7

MIDDLEBOROUGH WWTP

NEMASKET RIVER LOADING COMPARISONS

8/12-15/75

RIVER MILE (STATION)	FLOW (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O. (mg/l) min	D.O. (mg/l) avg	D.O. (mg/l) max	(°F) Avg temp	Avg % sat
5.6(NK03A)	21.5*	1.2	139	8.2	952	0.02	2.3	0.08	9.3	4.5	5.5	6.7	76	65
3.7(NK04)	31	3.0	502	1.8	301	0.49	82	0.22	37	2.1	2.8	4.1	76	33
2.6(NK05)	41.8*	2.6	587	2.0	451	0.32	72	0.33	74	1.3	2.6	4.7	77	31
0.5(NK06)	60	2.0	648	3.0	972	0.20	65	0.48	156	1.6	2.4	3.7	77	29

7/9-10/80

RIVER MILE (STATION)	FLOW (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O. (mg/l) min	D.O. (mg/l) avg	D.O. (mg/l) max	(°F) Avg temp	Avg % sat
5.6(NK03A)	18*	3.0	292	0	0	0.01	1.0	0.07	6.8	4.7	7.8	10.6	71	88
3.7(NK04)	28	2.7	408	4.5	680	0.04	6.0	0.48	73	5.3	7.0	8.6	72	79
2.6(NK05)	38	2.7	554	6.0	1231	0.07	14	0.41	84	4.6	6.0	7.4	71	67
0.5(NK06)	-	-	-	-	-	-	-	-	-	4.3	-	-	69	-

* Instream Flow Measurement

- No data collected

TABLE B-8

MILFORD WWTP

CHARLES RIVER LOADING COMPARISONS

8/6/86

RIVER MILE (STATION)	FLOW (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O. (mg/l) min	D.O. (mg/l) avg	D.O. (mg/l) max	(°F) Avg temp	Avg % sat
73.9(CH03)	4.4	2.4	57	0.5	12	0.10	2.4	0.09	2.1	2.0	3.0	4.1	68	33
73.0(CH04)	8.8*	8.4	399	3.0	143	11	523	3.3	157	2.1	2.8	3.6	70	31
72.0(CH05)	9.0	6.9	335	2.5	122	11	535	3.3	160	1.4	1.9	2.4	70	21
70.3(CH06)	9.5	3.9	200	1.0	51	7.0	359	2.6	133	2.6	3.2	3.8	75	37

8/4/88

RIVER MILE (STATION)	FLOW (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O. (mg/l) min	D.O. (mg/l) avg	D.O. (mg/l) max	Avg temp	Avg % sat
73.9(CH03)	3.32	5.1	91	3.0	54	0.40	7.2	0.11	2.0	2.0	4.7	7.5	80	58
73.0(CH04)	8.34*	4.5	203	2.5	113	0.29	13	0.09	4.1	3.8	5.5	7.2	80	68
72.0(CH05)	8.7	2.4	113	3.0	141	0.09	4.2	0.09	4.2	2.5	3.4	4.3	80	42
70.3(CH06)	9.5	2.4	123	2.5	128	0.11	5.6	0.08	4.1	5.3	6.4	7.6	82	80

* Instream Flow Measurement

TABLE B-9

NORTH ATTLEBOROUGH WWTP

TEN MILE RIVER LOADING COMPARISONS

7/5/73

RIVER MILE** (STATION)	FLOW (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O. (mg/l) min	D.O. (mg/l) avg	D.O. (mg/l) max	(°F) Avg temp	Avg % sat
15.6(TM06)	12.9*	4.5	313	20	1393	0.2	14	0.32	22	6.1	7.0	7.6	74	81
15.2(TM07)	17.5	7.8	737	21	1985	1.36	129	1.00	94.5	5.6	6.7	7.8	73	77
14.2(TM08)	24	5.4	700	16	2074	1.5	194	0.82	106	4.3	5.1	6.4	73	59
12.6(TM09)	25*	6.0	810	22	2970	0.96	130	0.66	89	3.7	5.0	6.1	74	58

7/24-25/84

RIVER MILE** (STATION)	FLOW (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O. (mg/l) min	D.O. (mg/l) avg	D.O. (mg/l) max	(°F) Avg temp	Avg % sat
15.6(TM06)	10.2*	1.2	66	3.8	209	0.09	5.0	0.28	15	6.3	7.0	7.8	75	82
14.2(TM07)	15	2.9	235	4.8	389	0.19	15	0.58	47	5.7	6.9	8.3	73	79
13.4(TM07A)	27	2.3	335	6.0	875	0.15	22	0.42	61	5.6	6.5	7.9	73	75
13.0(TM08)	28	1.8	272	8.0	1210	0.11	17	0.32	56	5.6	6.3	6.9	72	72
12.6(TM08A)	29	1.8	282	5.3	830	0.14	22	0.32	50	5.1	6.1	6.9	72	69

* Instream Flow Measurement
** Stations differ from year to year

TABLE B-10

UBWPAD

BLACKSTONE RIVER LOADING COMPARISONS

6/19/73

RIVER MILE (STATION)	FLOW (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O. (mg/l) min	D.O. (mg/l) avg	D.O. (mg/l) max	(°F) Avg temp	Avg % sat
51.3(BS08)	30	3.6	583	12	1944	0.29	47	0.14	23	6.3	7.2	7.7	63	74
47.9(BS09)	51.4*	23	6385	27	7474	2.4	666	0.06	17	2.5	3.8	5.6	65	40
46.0(BS10)	93	29	14564	36	18079	4.3	2159	3.0	1507	1.8	2.2	2.8	66	23
43.6(BS11)	105	21	11907	29	16443	4.7	2665	2.3	1304	1.8	3.7	5.1	65	38
42.2(BS12)	112	16	9677	24	14515	4.6	2782	2.0	1210	0.8	2.1	3.0	65	22

6/19/85

RIVER MILE (STATION)	FLOW (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O. (mg/l) min	D.O. (mg/l) avg	D.O. (mg/l) max	(°F) Avg temp	Avg % sat
51.3(BS08)	30	3.0	486	2.0	324	0.02	3.2	0.13	21	7.9	8.3	8.7	69	91
47.9(BS09)	51.1*	9.9	2732	12	3311	0.95	262	0.45	124	4.1	5.9	7.6	68	64
46.0(BS10)	90	7.2	3499	8.5	4131	5.7	2770	3.4	1652	4.1	5.2	6.2	68	57
43.6(BS11)	105.2*	7.2	4090	2.5	1420	5.2	2954	1.1	625	4.1	5.7	7.2	70	63
42.2(BS12)	112	5.4	3266	3.0	1814	5.0	3024	0.86	520	3.2	5.3	7.4	69	58

* Instream Flow Measurement

TABLE B-10 (CONTINUED)

UBWPAD

BLACKSTONE RIVER LOADING COMPARISONS

6/14/88

RIVER MILE (STATION)	FLOW (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O. (mg/l) min	D.O. (mg/l) avg	D.O. (mg/l) max	(°F) Avg temp	Avg % sat
51.3(BS08)	21*													
47.9(BS09)	43	4.8	1115	7.5	1742	0.42	98	0.06	14	4.8	5.2	5.5	71	62
46.0(BS10)	93	6.3	3164	16	8035	1.2	603	0.44	221	5.0	6.1	7.2	69	67
43.6(BS11)	105	5.7	3232	10	5670	0.99	561	0.40	227	6.2	6.6	7.0	70	73
42.2(BS12)	112	3.9	2359	5.5	3326	1.1	665	0.42	254	6.7	7.1	7.5	69	78

* Instream Flow Measurement

TABLE B-11

WARE WWTP

WARE RIVER LOADING COMPARISONS 7/80 - 7/85

7/15/80

RIVER MILE (STATION)	FLOW (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O. (mg/l) min	D.O. (mg/l) avg	D.O. (mg/l) max	(°F) Avg temp	Avg % sat
11.7(WA08)	61**	1.5	494	2.5	824	0.21	69	0.08	26	7.4	7.9	8.6	71	92
8.8(WA09)	77*	2.4	998	3.5	1455	0.32	133	0.16	67	5.9	7.2	8.5	74	84
8.3(WA09A)	80	1.5	648	1.5	648	0.15	65	0.09	39	4.3	7.2	9.6	74	85
4.4(WA10)	103	2.1	1168	2.5	1391	0.10	56	0.12	67	5.2	6.6	7.5	74	77

7/15/85

RIVER MILE (STATION)	FLOW (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O. (mg/l) min	D.O. (mg/l) avg	D.O. (mg/l) max	(°F) Avg temp	Avg % sat
11.7(WA08)	63	2.1	714	3.0	1021	0.13	44	0.05	17	-	7.9	-	73	91
8.8(WA09)	79*	1.5	427	2.5	1067	0.0	0	0.09	38	-	7.6	-	72	86
8.3(WA09A)	82	1.8	797	4.0	1771	0.11	49	0.09	40	-	7.8	-	72	88
4.4(WA10)	105	2.1	1191	3.5	1985	0.08	45	0.15	85	-	6.5	-	74	75

* USGS Gage Flow Measurement
** Instream Flow Measurement

TABLE B-12

WARE WWTP

WARE RIVER LOADING COMPARISONS 8/72 - 8/85

8/29/72

RIVER MILE (STATION)	FLOW (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O. (mg/l) min	D.O. (mg/l) avg	D.O. (mg/l) max	(°F) Avg temp	Avg % sat
77.7(WA08)	60	3.6	1166	7.0	2268	0.10	32	0.16	52	7.5	8.1	8.8	74	94
8.8(WA09)	76*	3.4	1395	6.0	2462	0.10	41	0.20	82	3.3	5.9	8.2	74	68
8.3(WA09A)	80	3.6	1555	8.0	3456	0.10	43	0.20	86	3.0	5.6	8.5	74	65
4.4(WA10)	100	4.2	2268	8.0	4320	0.09	49	0.08	43	4.5	6.2	7.4	73	71

8/21/85

RIVER MILE (STATION)	FLOW (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O. (mg/l) min	D.O. (mg/l) avg	D.O. (mg/l) max	(°F) Avg temp	Avg % sat
11.7(WA08)	70	2.0	756	2.0	756	0.07	26	0.14	53	-	7.9	-	8	86
8.8(WA09)	84*	1.8	816	1.0	454	0.04	18	0.20	91	-	8.7	-	68	95
8.3(WA09A)	90	1.8	875	1.0	486	0.06	29	0.22	107	-	8.4	-	67	90
4.4(WA10)	110	1.8	1069	1.0	594	0.04	24	0.20	119	-	6.9	-	68	75

* USGS Gage Flow Measurement

TABLE B-13

WESTBOROUGH WWTP

ASSABET RIVER LOADING COMPARISONS

7/17/85

RIVER MILE (STATION)	FLOW* (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O. (mg/l) avg **	(°F) Avg temp	Avg % sat
31.8(AS01)	0.1	8.1	4.4	9.0	4.9	0.16	0.9	0.19	1.0	4.4	75	51.5
29.2(AS05)	5.5	19	564	9.5	282	3.8	113	3.1	92	0.8	70	9.0
28.3(AS06)	7.5	17	689	7.5	304	4.1	166	2.6	105	0.5	71	5.6
26.5(AS07)	11.0	11	653	8.0	473	6.3	374	3.0	178	0.2	72	2.2
24.2(AS09)	14.1	5.4	411	3.0	228	3.8	289	3.0	228	1.1	71	12.4

9/1/87

RIVER MILE (STATION)	FLOW* (cfs)	BOD mg/l	BOD #/day	SS mg/l	SS #/day	NH3 mg/l	NH3 #/day	TP mg/l	TP #/day	D.O. (mg/l) avg **	(°F) Avg temp	Avg % sat
31.0(AS02)	0.1	2.4	1.3	5.0	2.7	0.05	0.0	0.5	0.3	7.3	65	77
29.2(AS05)	5.5	2.1	62	3.0	89	0.1	3.0	3.3	98	6.5	69	71.5
28.3(AS06)	7.5	2.4	97	5.0	203	0.15	6.1	3.1	126	6.5	67	70
26.5(AS07)	11.0	2.4	143	2.5	149	0.13	7.7	2.9	172	6.0	67	64.5
24.2(AS09)	14.1	1.8	137	2.5	190	0.04	3.0	1.5	114	7.5	66	80

* Flow Measured at USGS Gage, River Mile 7.7
** No min or max DO data

APPENDIX C

TABLE C-1

BROCKTON WWTP COST ANALYSIS
(All loadings in lbs/day)

PARAMETER	AVG BEFORE LOADING	AVG AFTER LOADING	CHANGE IN LOADING	% REMOVED	lbs/DAY REMOVED/ $ MILLION	ADJUSTED*** REMOVAL/ $ MILLION	lbs/DAY REMOVED/ $M-1988**	ADJUSTED REMOVAL/ $M-1988
BOD	1540	210	1330	52.2	41.4	62.0	25.5	38.1
SS	809	204	605	23.8	18.8	28.2	11.6	17.3
NH3	541	30	511	20.1	15.9	23.8	9.8	14.6
TP	201	101	100	3.9	3.1	4.7	1.9	2.9
TOTAL	3091	545	2546	100	79.2	118.7	48.7	72.9

* $32.136 Million Original Cost
** $52.253 Million 1988
*** At 66.8 Percent of 8.6 MGD Capacity - Adjusted to full Capacity

TABLE C-2

BROCKTON WWTP COST ANALYSIS
(All loadings in lbs/day)

PARAMETER	AVG BEFORE LOADING	AVG AFTER LOADING	CHANGE IN LOADING	% REMOVED	lbs/DAY REMOVED/ $ MILLION	ADJUSTED*** REMOVAL/ $ MILLION	lbs/DAY REMOVED/ $M-1988**	ADJUSTED REMOVAL/ $M-1988
BOD	5024	680	4344	27.1	88.1	128.0	63.1	91.7
SS	10,226	173	10,053	62.8	203.8	296.2	146.1	212.3
NH3	2032	682	1350	8.4	27.4	39.8	19.6	28.5
TP	584	328	256	1.6	5.2	7.5	3.7	5.4
TOTAL	17,866	1863	16,003	100	324.5	471.5	232.5	337.9

* $49.332 Million
** $68.818 Million 1988
*** At 68.8 % of 18 MGD Capacity Adjusted to full Capacity

TABLE C-3

LEOMINSTER WWTP COST ANALYSIS
(All loadings in lbs/day)

PARAMETER	AVG BEFORE LOADING	AVG AFTER LOADING	CHANGE IN LOADING	% REMOVED	lbs/DAY REMOVED/ $ MILLION	ADJUSTED*** REMOVAL/ $ MILLION	lbs/DAY REMOVED/ $M-1988**	ADJUSTED REMOVAL/ $M-1988
BOD	1461	473	988	42.4	38.2	68.8	27.4	49.3
SS	1741	750	991	42.5	38.3	69.0	27.4	49.4
NH3	570	386	184	7.9	7.1	12.8	5.1	9.2
TP	208	40	168	7.2	6.5	11.7	4.7	8.4
TOTAL	3980	1649	2331	100	90.1	162.3	64.6	116.3

* $25.880 Million
** $36.103 Million 1988
*** At 55.5 percent of 9.3 MGD Capacity - Adjusted to full Capacity

TABLE C-4

MANSFIELD WWTP COST ANALYSIS
(All loadings in lbs/day)

PARAMETER	AVG BEFORE LOADING	AVG AFTER LOADING	CHANGE IN LOADING	% REMOVED	lbs/DAY REMOVED/ $ MILLION	ADJUSTED*** REMOVAL / $ MILLION	lbs/DAY REMOVED/ $M-1988**	ADJUSTED REMOVAL/ $M-1988
BOD	332	24	308	34.7	9.9	28.5	7.7	22.3
SS	467	15	452	51.0	14.5	41.8	11.3	32.7
NH3	83	1.0	82	9.2	2.6	7.6	2.1	5.9
TP	49	3.7	45	5.1	1.4	4.2	1.1	3.3
TOTAL	931	44	887	100	28.4	82.1	22.2	64.2

* $31.262 Million
** $39.953 Million 1988
*** At 34.6% of 3.13 MGD Capacity - Adjusted to full Capacity

TABLE C-5

MIDDLEBOROUGH WWTP COST ANALYSIS
(All loadings in lbs/day)

PARAMETER	AVG BEFORE LOADING	AVG AFTER LOADING	CHANGE IN LOADING	% REMOVED	lbs/DAY REMOVED/ $ MILLION	ADJUSTED*** REMOVAL/ $ MILLION	lbs/DAY REMOVED/ $M-1988**	ADJUSTED REMOVAL/ $M-1988
BOD	1116	46	1070	32.5	180.0	487.9	88.2	238.9
SS	2193	77	2116	64/2	356.0	964.9	174.4	472.5
NH3	114	3.3	111	3.4	18.7	50.6	9.1	24.8
TP	(47)	(35)	(12)	***	****	****	****	****
TOTAL	3423	126	3297	100	554.7	150.4	271.7	736.2

* $5.943 Million
** $12.136 Million 1988
*** At 36.9 percent of 2.5 MGD Capacity - Adjusted to full Capacity
**** No Phosphorus Removal

TABLE C-6

MILFORD WWTP COST ANALYSIS
(All loadings in lbs/day)

PARAMETER	AVG BEFORE LOADING	AVG AFTER LOADING	CHANGE IN LOADING	% REMOVED	lbs/DAY REMOVED/ $ MILLION	ADJUSTED*** REMOVAL/ $ MILLION	lbs/DAY REMOVED/ $M-1988**	ADJUSTED REMOVAL/ $M-1988
BOD	662	105	557	40.1	29.0	39.3	26.1	35.3
SS	450	67	383	27.6	20.0	27.0	17.9	24.3
NH3	365	18	347	25.0	18.0	24.5	16.2	22.0
TP	109	7.8	101.2	7.3	5.3	7.1	4.7	6.4
TOTAL	1586	197.8	1388	100	72.3	97.9	64.9	88.0

* $19.201 Million
** $21.371 Million 1988
*** At 73.9% of 4.3 MGD Capacity - Adjusted to full Capacity

TABLE C-7

NORTH ATTLEBOROUGH WWTP COST ANALYSIS
(All loadings in lbs/day)

PARAMETER	AVG BEFORE LOADING	AVG AFTER LOADING	CHANGE IN LOADING	% REMOVED	lbs/DAY REMOVED/ $ MILLION	ADJUSTED*** REMOVAL / $ MILLION	lbs/DAY REMOVED/ $M-1988**	ADJUSTED REMOVAL/ $M-1988
BOD	976	131	845	40.0	49.5	60.9	30.4	37.5
SS	1189	97	1092	51.8	63.9	78.7	39.3	48.4
NH3	180	56	124	5.9	7.3	8.9	4.5	5.5
TP	78	29	49	2.3	2.9	3.5	1.8	2.2
TOTAL	2423	313	2110	100	123.6	152.0	76.0	93.6

* $17.079 Million
** $27.770 Million 1988
*** At 81.2 percent of 4.6 MGD - Adjusted to fall Capacity

TABLE C-8

UBWPAD COST ANALYSIS
(All loads in lbs/day)

PARAMETER	AVG LAOD lbs/DAY BEFORE UPGRADING	AVG LOAD ADJUSTED*** BEFORE NITRIFI-CATION	AVG LAOD AFTER NI-TRIFICA-TION	CHANGE lbs/DAY WITH SECOND-DARY	WITH ADJUSTED NITRI-FICA-TION	TOTAL CHANGE	% REMOVED	ADJUSTED*** REMOVED/ $ MILLION	ADJUSTED*** REMOVAL/ $ MILLION	lbs/DAY REMOVED/ $M - 1988	ADJUSTED REMOVAL/ $M - 198
BOD	15,560	3050	993	12,510	2057	14,567	52.3	615.6	109965	277.3	490.8
SS	19,624	4829	1491	14,795	3338	11,457	41.1	484.2	856.9	218.1	386.0
NH3	1997	3403	145	-1406	3258	1852	6.6	78.3	138.5	35.3	62.4
TP	(837)	(768)	(472)	(69)	(296)	(365)	****	****	****	****	****
TOTAL	37,181	10,282	2629	27,305 (NO NIT. INCLUDED)	7653	27,876	100	1178.1	2084.9	530.7	939.2

* $23.664 Million
** $52.529 Million 1988
*** At 56.5% of 56 MGD Capacity - Adjusted to full Capacity
**** No phosphorus Removal

TABLE C-9

WARE WWTP COST ANALYSIS
(All loadings in lbs/day)

PARAMETER	AVG BEFORE LOADING	AVG AFTER LOADING	CHANGE IN LOADING	% REMOVED	lbs/DAY REMOVED/ $ MILLION	ADJUSTED*** REMOVAL/ $ MILLION	lbs/DAY REMOVED/ $M-1988**	ADJUSTED REMOVAL/ $M-1988
BOD	945	58	887	45.6	270.1	931.4	193.6	667.7
SS	970	30	940	48.3	286.2	987.0	205.2	707.6
NH3	109	7	102	5.2	31.1	107.1	22.3	76.8
TP	30	14	16	0.8	4.9	16.8	3.5	12.0
TOTAL	2054	109	1945	100	592.3	2042.3	424.6	1464.1

* $3.284 mILLION
** $4.581 mILLION 1988
*** At 29 percent of 2.0 MGD Capacity - Adjusted to full Capacity

TABLE C-10

WESTBOROUGH WWTP COST ANALYSIS
(All loadings in lbs/day)

PARAMETER	AVG BEFORE LOADING	AVG AFTER LOADING	CHANGE IN LOADING	% REMOVED	lbs/DAY REMOVED/ $ MILLION	ADJUSTED*** REMOVAL/ $ MILLION	lbs/DAY REMOVED/ $M-1988**	ADJUSTED REMOVAL/ $M-1988
BOD	1315	217	1098	32.4	36.3	86.3	33.6	80.1
SS	2163	92	2071	61.1	68.4	162.8	63.5	151.1
NH3	231	10	221	6.5	7.3	17.4	6.8	16.1
TP	(160)	(139)	(21)	***	****	****	****	****
TOTAL	3709	319	3390	100	112.0	266.5	103.9	247.3

* $30.297 Million
** $32.631 Million 1988
*** At 42% of 7.68 MGD Capacity - Adjusted to full Capacity
*** No Phosphorus Removal

APPENDIX D

FEDERAL/STATE FUNDING DESCRIPTION

The Federal Construction Grants Program was established in 1956 by the Federal Water Pollution Control Act to help provide grants for the construction of wastewater treatment facilities. The federal program was established with the intention of the states and local municipalities eventually assuming full responsibilities for the financing.

Grant assistance was divided into three individual categories; step 1, the study and planning phase, step 2, the design of the wastewater treatment plant (WWTP) phase, and step 3, construction of the WWTP. Initially the federal grants funded the step 1 and step 2 stages, and no state grants were provided. State grants for the steps 1 and step 2 were included in the state grant portion of the step 3 payments. The amount of the federal and state grants is based on the total project which is eligible for financial assistance.

Initially, the federal government offered grants for 75% of the total eligible cost. The state grants would fund 15%, and the local municipalities would be responsible for the remaining 10%. In 1981 an amendment to the Federal Clean Water Act (CWA) reduced the federal share from 75% to 55%. The state grant was increased from 15% to 35% to account for the difference and to keep the local share at 10%. In addition, the 1981 amendments to the Clean Water Act provided a 20% federal bonus grant in addition to the 55% grant for the construction of treatment plants that used innovative and alternative (I/A) processes and techniques. The bonus was applied to any WWTP constructed after October 30, 1978 which included I/A wastewater treatment processes. The state grant assistance on I/A processes was adjusted to keep the local share at 6% of eligible costs. In other words, a project that was 100% I/A eligible could receive 94% (75% EPA and 19% state) grant assistance with the local share only 6% versus 10% if the project employed conventional wastewater treatment processes. In 1987, Congress passed the Water Quality Act which amended and reduced the federal grant contribution to 35%. The state share was adjusted to 55% while the local share remained at 10%. The new amendments also included a schedule for eliminating federal grant funding.

The authorization of the Water Quality Act in 1987 introduced a turning point in financing for construction of municipal wastewater treatment facilities. The Act now calls for the phase out of the present federal construction grants program by 1991, and, to help fill the void, the creation of State Revolving Funds (SRF's). To assist in making this transition, Congress has authorized the appropriation of SRF start-up money in the form of capitalization grants to states. This start-up money will help provide a permanent, state-administered revolving fund to assist communities in financing water pollution abatement facilities. The most common use of these funds will be for low interest loans to communities. There will be no federal construction grants awarded to communities after 1990. At this point, states and municipalities will have the sole responsibility for providing financing to meet enforceable requirements of the Clean Water Act. As early as 1988, states can use their SRF's to provide loans and other types of financial assistance to municipalities.

(From "Transition" - NEIWPCC - May 1988). The Massachusetts Legislature has a bill which will establish a SRF. This proposed financial assistance program is expected to become law by the spring of 1989.

The State grant program also provides funds for combined sewer overflows (CSO's) separation and elimination, $100 million in state funds for a 90 % state only grant for infiltration and inflow (I/I) analysis, sewer system evaluation surveys and design/construction and rehabilitation of leaking sewage collection lines. There is also a state $ 25 million dollar collection systems construction grants program to fund 50 % of eligible money for building sewers to new or expanded developments.

APPENDIX E

Construction Cost Index History

YEAR	ANNUAL* AVERAGE	1988/YEAR FACTOR
1974	2020	2.236
1975	2212	2.042
1976	2401	1.881
1977	2578	1.752
1978	2778	1.626
1979	3003	1.504
1980	3237	1.395
1981	3535	1.278
1982	3825	1.181
1983	4056	1.113
1984	4146	1.089
1985	4195	1.077
1986	4295	1.051
1987	4401	1.026
1988	4516	1.000

Taken from Engineering News Record Magazine

* The Annual average is based on average cost for 200 hours of common labor at the 20-city average of bricklayers', carpenters', and structural ironworkers' rates, plus 25 cwt of standard structural steel shapes at the mill price, plus 22.56 cwt (1.128 tons) of portland cement at the 20-city price, plus 1,088 board-ft of 2x4 lumber at the 20-city price.

APPENDIX F

LIST OF ABBREVIATIONS

7Q10 - Seven-Day, Ten-Year Low Flow

BOD - Biochemical Oxygen Demand

cfs - Cubic feet per second, flow measurement

CSO - Combined Sewer Overflow

DEQE - Department of Environmental Quality Engineering

DO - Dissolved Oxygen

DWPC - Division of Water Pollution Control

EPA - Environmental Protection Agency

GPD - Gallons per day

I/I - Infiltration/Inflow

lbs/day- Pounds per day

MGD - Million Gallons per Day

mg/l - Milligrams per liter

NH3 - Ammonia - Nitrogen

NPDES - National Pollutant Discharge Elimination System

POTW - Publicly Owned Treatment Works

SS - Suspended Solids

STP - Sewage Treatment Plant

TP - Total Phosphorus

WWTP - Wastewater Treatment Plant

#/day - Pounds per day